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FOR THE

PROMOTION OF THE MECHANIC ARTS.

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EDITORIAL.

The Introduction of the Metric System of Measures and Weights.—It is a reasonable presumption from the action of the United States Government that within some brief space of time the commencement of the introduction of the metric system will have been effected.

The advantage of a decimal system in computation is too generally admitted to need re-statement. The confusion of our English measures and weights, and the complexity of their divisions, is also unquestionable. The student and the scientific man have already made the change. The *standard* measures and weights of the United States have for years been metric, and the great survey of the coast is carried on by meters, and the people generally desire the extension of the decimal notation beyond the money. The very fact that money values are computed in decimals has incapacitated not a few persons whose figures have rarely gone beyond their purchases and sales, or payments or receipts, from easy and free use of the irregular division of other quantities. Thus the relationship of the

inch to the foot (and more especially the duodecimal notation of the square or cubic foot) that of the ounce to the pound, that of the foot to the rod, or the rod to the mile or acre, the division of measure of bulk, wet or dry, is not clear in the minds of most people. Of all the irregular divisions of units, those only which relate to time can be said to be generally comprehended. It is probable that the English—men, women, or children—with the anomaly (to us) of pounds, shillings and pence in their daily life, are more appreciative and are better educated in the use of other arbitrary divisions than we are. The facility of calculation in £. s. d., once secured and constantly practiced, gives a great aptitude in sums of tons, quarters, stones and pounds, gallons, quarts and pints, bushels, pecks or quarts, or some duodecimals of $'$, $''$, $'''$. It may be almost questioned whether we have not lost as much from our partial adoption of the decimal system, as we have gained at this time if we stop with money.

The value of an easy notation cannot be overstated. It is the arrangement of things by rows in place of a heap—the grouping of things of the same kind—the arrangement of the problem so that it may be relative to things of any nature, without regard to the things but only to the quantities—the briefest statement of facts in issue solely. An answer is easy if a question be not confused. Thus, one of the recognized fountains of modern advancement was the facility given to the ordinary processes of arithmetic by the introduction of the *Arabic* digits and zero.

Any process of actual multiplication, for instance, 873 by 654, was as easy as a mental operation, as a conception of resulting value, to the Roman or Greek of antiquity, as to the schoolboy in America; but the facility of the performance, unless such Roman or Greek was of that peculiar mental development which is found in but two or three individuals in a century of time, is greatly in favor of the schoolboy. In truth, not only the processes of arithmetic but the whole scientific ability of an age was lost in the Roman and Greek characters. Let any one essay a few sums in Roman numerals and he will recognize the difficulty.

The next great source of modern knowledge was discovered when algebra was introduced. The simple notation of letters to represent quantities, and of signs and positions to represent processes performed, or to be performed with them, as a substitution for the verbal description of those quantities and of the operations applied to them,

(a mere relief from verbiage,) has given the human mind control of the universe. From the bare arithmetical algebra of the 13th century has grown higher applications, positive and definite, embracing all the conclusions and results of ancient geometry and extending them illimitably. Flowing from this came Newton's fluxions and Leibnitz calculus. No stronger example of the result of an error in selection of notation can be found than that which appeared from the English use of Newton's method for a century, while the French surpassed them in all mathematical enquiries, by their adaptation of the simpler forms for the same process derived from Leibnitz.

It may seem to many that the comparison of results attained in higher mathematics, with those to be anticipated as proceeding from so simple a matter as the establishment of a new measure, or some weights for daily use is far-fetched, but it must be recognized that as our language is based upon A, B, C, our figures on 1, 2, 3, so our philosophy is based upon the condition of things in nature, on dimension and weight. It is not that the length of a meter presents any particular advantage, nor even does the decimal division offer any great facility of use or comprehension, but the meter is well enough for a unit of length, and the decimal divisions accord with our numeration by which all our calculations of quantity, real or numerical, are made, and beyond this the metric *system* gives a relationship of all measures, of dimensions, and of all weights, to those dimensions which relationship does not now exist in our multifarious standard. Any other length would answer equally well for a base, and the question at one time was, what other length would be most suitable. It can be admitted for the purpose of measurement that the unit should be a convenient length for repetition, and nine-tenths of the measurements used by the *English* nations are taken in the yard. One-half (the female moiety) of the entire population *think* in no other measure, beside all the male part of the community who make or deal in textile fabrics. With these are associated the engineer and excavator who know only the cubic yard as a measure of bulk.

This yard dimension is nearly quite suitable for its purpose. It is admitted on all hands that its extension three or four inches would not only be not inconvenient, but would a little facilitate measurement by hand. It seems to follow, therefore, that more than one half our population are ready for the French meter as a new yard-stick. The sub-divisions of the yard are in too unsettled state to be considered.

Here in Philadelphia it is probable that the nail has passed from the recollection, or at least from the practice of the salesmen, and that the quarter of a yard is the least recognizable measure, when the half a quarter is the division of the new unit. The tailors use the 36 inches, but such use is special and runs into inches only, as 56 inches in place of 1 yard and 20 inches. Admitting the meter, no one supposes any other than a decimal division. It is demonstrable that special numerations of 7, 8, 12, 16, 20, 60, present in the end no advantages of method for the new and reformed world; that unless we could have simple units to deal with, such as never occur in nature, no superiority is found in one over the other. One consideration that can at once overthrow any argument as to absolute superiority of any numeration over another is found in the logarithmic tables, which would appertain to any selected base. Thus a set of logarithms on the modulus of 8 would be no more simple than those on 10. The real limit of a numeration is how far the average mind can carry the simple multiplication table, and beyond ten times ten is clearly inadmissible. Each one of the professions has come to a decimal division. The surveyor (about the beginning of this century) came to a chain of 4 rods (66 feet) with 100 links of 7″·92 each, and the links are divided decimally. The engineer of more recent times has come to another chain of 100 feet, with decimal divisions of a foot into tenths of 1″·2 each, also decimally divided into 12-100ths ($\frac{1}{8}$ nearly.) The machinist has, in closer calculation, come to hundredths of an inch, (and hundredths of a pound for weight.) These examples could be greatly extended if space admitted. Up to this time, these and similar efforts to find individual relief from original error have led to further confusion.

The merit of the metrical system lies in the convertibility of the units of length, surface and contents, or bulk to those of weight. The substitution of *some division*, aliquot, presumably decimal, of the cubic unit, for the gallon, and all its anomalous multiples, and the establishment of *some* ratio of weights with the same cubic unit, is what the *metric system* proposes. To many readers the very words specific gravity are a mystery, and a clear conception or free use of the resulting laws, except by the student or scientific man, is almost uncommon. Yet this elementary condition for all matter is the groundwork of natural philosophy. The laws of physics and the facts of chemistry are based upon it. We are burdened as completely with our

present notation of measures and weights as the Chinese people are with their language, and there are those among us as proud of having surmounted the difficulties as the most learned of mandarins, with the knowledge of a hundred thousand characters; and, like the Chinamen, have found themselves nearly incapable of making their acquirement of use.

Referring to the original assumption that the change is on the eve of accomplishment, the briefest consideration of the effect in some ways may not be inappropriate. The fear that great inconvenience or loss will ensue, is quite unfounded. The trader can be safely trusted, that he will not lose by the new yard-stick; the coal dealer by the new ton; the market gardener by the new quarter of a peck; the grocer by the new pound. The loss of measuring sticks and weights and measures is admitted, but the nation will survive that revolution, although the writer of this may mourn over the two-foot rule which has been his pocket companion for nearly thirty years. A people who have ceased to *think* in 7∫6 to the dollar, and who have lost the "levy" and "fippenny-bit" within twenty years, may cease to *think* in other incongruities little less absurd. In the business of the world, all our divisions are approximate, and exactness is not demanded or attained; the general purpose of measurement will be answered by the consideration that the meter is a long yard, the decimeter a nail, or the width of the natural foot in place of its length. The liter is a large quart, and weighs a kilogram, which is over two pounds. The ton is the same as ever (2240 lbs.), etc., etc. Even for more accurate measures, it is not proper to admit that confusion or error will ensue. Take, for example, we have here in Philadelphia the plan of the city of *squares*, with 50 feet wide streets, and 400 feet squares of building ground. The awkwardness of the new dimension of the 131·236 meters and decimal parts may be admitted, when we consider the present unit is 100 feet, and the number simply 4 in English measure.

But unfortunately no 400 feet exists. Even the *feet* do not exist. For the standard of measure for Philadelphia surveyors is not only not United States Standard, but it varies in different parts of the city. There are two standards at least, one 8½ inches in excess in 400 feet, and the other, 5 inches in 460 feet. While even to these standards the 400 feet to a square, will vary one to three feet. The streets are not straight, nor at right-angles. And after all, the lots are divided

with so much irregularity that units of greater than eighths of inches could not express them in even numbers. In Philadelphia, as in other cities and lands, a sale or purchase of ground is to existing boundaries fixed by description with measurements, more or less.

The measure of the mechanic is generally in feet and inches, but the practical unit of considerable lengths is *two feet*, with a numeration of 24 inches. This awkward unit is discarded by all except the workmen in wood or metal. The favorite unit for small divisions of the machinist is an inch. In the mechanic arts, perhaps more figures refer to the inch length than to any other. Yet it can be averred that very little of workshop practice is in even inches, or even exact halves, quarters, eighths or sixteenths of inches. The commercial bars of iron—squares, flat, or rounds—have practical limits of accuracy—plates are but nominal. It is well known, that it is impossible to roll a sheet of iron to uniform thickness. The distortion of the rolls by expansion from heat produces a convex lens when rolling is commenced, and a concave one afterwards. And the thin sheets, those less than ¼ inch in thickness are rolled to *gauges* which bear such a wonderful relation to all measurements and to each other as to call for as general fault-finding as they do following. (The irregular reduction of the Burmingham gauge have been *simplified* by an "American gauge," where each successive plate is reduced 0 890522 times that of the one above it). With great care, Sir Jos. Whitworth made some standard gauges of inch cylinders and holes, with 16th variation, and they exist or have been copied in, possibly at most, one in ten of the larger workshops of the world. But they are used as standards of measurements, not as inches, and it is safe to say that the 16th divisions are quite as frequently employed as the even numbers. As measurements to follow, the workman's eyes fail at the 32d of an inch, and he *never* trusts to fit one part to another by comparison of measurements. He works to a *guage* or to *a caliper*. Except that a 3-inch shaft approximates towards 3 inches in diameter, it might as well be a No. 3 shaft. The effect of changing in the machine shop to the metrical system, will not be felt in any sizes now in use, or any gauges now made. The 3-inch shaft will yet remain 2 15-16 inches approximate diameter, although it may be stated *at some future time* as ·0746 meters, or more accurately 74·612 millimeters. When it will be found that a variation of one in the next to the last place of the decimals (2 in place of 1) will mean

$\frac{1}{200}$ part of an inch, and the omission of the last two figures (12) means $\frac{1}{200}$ part of an inch. It must be noticed that the number of characters to express 2 15-16 (6 in all) does not differ from the number used in the metrical system, 74·612 (6 in all). The excellence of machine shop practice to-day lies in the use of gauges to work from, and repetition of parts. No measurement or description could be adequate to reproduce one of these gauges, nor would any scale drawing suffice; the curves and shapes of the parts of a gun or of a sewing machine, can only be produced by the machines used and *by working to gauge* with those machines. The simpler gauges can be measured, but they bear a small ratio to those which cannot be in real work.

The proportion of machinery to affect a given purpose will be unaffected by any standard of length or weight applied to the parts.

In all probability, *the name* will remain long after the inch measure ceases to exist. Thus in the manufacture of wrought iron tubes in 1815 or '16, the effort was to supply tubes having internal diameters $1\frac{1}{2}$ inches, $1\frac{1}{4}$ inches, 1 inch, $\frac{3}{4}$ inch, $\frac{1}{2}$ inch, etc., and the tubes thus supplied were *named* of these diameters. They were joined or coupled by screws on their outsides, and consequently the outsides required exactness, although the insides might vary a little. Presently it was found practicable to reduce the thickness of iron employed, but the outside dimension was necessarily maintained to connect with tubes previously made, and eventually the tubes have come to be only *nominally* of diameters, while they actually exceed nearly one-half times on some sizes. Wrought iron tubes of these nominal diameters are made and sold in France and Germany with as definite dimensions as though they referred to Whitworth gauges. * * * * * * *

The course of the United States to this time has been much the same as set forth in the fable of the lark and her young and the farmer; but there is reason to suppose that presently the farmer may commence on the harvest himself. The collection of revenue, both foreign and domestic, might be readily made in terms of the metrical system. Government purchase and contract; our post-office weights, and all similar transactions, might be enforced in the pursuance of this end. When this is done, we can see a commencement of the popular introduction of this system, and after this, we can begin to estimate the resulting effects of the change.

The introduction of the decimal system into our money has but just been accomplished. (It may be admitted in parenthesis, that it has left us with coins having no known or relative value; departures from all other coinages, and not interchangeable with each other, to say nothing of the greenback and legal tender bank bills). Many of our readers can recollect when the trading of the country was done in other denominations than dollars and cents, and some can recall when book-keeping was done in £. s. d. Over fifty years were spent in introducing the system so far that the *common purchaser* ceased to estimate his values in it. The final absorption of small depreciated silver incident to the postal-currency issue, alone terminated the effort. In France, for many years, the old nomenclature prevailed, and the diverse provincial values were hardly disturbed until the railway of 1830 broke down the local fashions.

The want of general education also precluded a rapid progress of any change in that country.

We may conclude the evil day is yet far off, but for all that, twenty years will have accomplished the task, and this step in human progress will have been taken.

Origin of the word wane-edged.—Can any of our readers give the derivation and correct orthography of the word *wain* or wane, as used in describing a want at the corner of a board or piece of lumber, occasioned by the log from which the piece was sawn being too small to square up?

Two Hundred and Fifty Tons of Brick Wall Carried Eighteen Inches without Injury.—About a month ago the Society St. Vincent de Paul determined to build on the vacant lots in the rear of their Twenty-third street building. A survey of the land being made, it was discovered that the wall of the five story brick livery stable adjoining encroached eighteen inches on their property. The owner was notified to remove the wall to the eastward, and Weeks & Brothers, builders, were authorized to tear it down and rebuild. Mr. Weeks did not like to pull down the wall, and proposed to move it bodily. The plan was ratified by several contractors, while others declared it could not be safely or successfully carried out.

Nowhere could be found in the history of building or house-moving an instance where a brick wall had been detached from a building and moved. The wall was thirty years old, and built of second-hand

brick; 70 feet high, about the same length, 16 inches wide at the base, and about 12 inches at the top. Its weight was 250 tons. Ten yellow-pine needles, 12 by 12 inches, planed on the upper surface, were let in horizontally under the wall, at equal distances, just above the foundation, and at right angles to its face. The upper surface of each needle was profusely greased, and a smaller needle with its planed surface down, inserted along each larger one. Spur-braces fixed at the foot in these upper timbers held the wall plumb. The jack-screws, working horizontally, were set at the ends of the ten upper needles. This being done, an eighteen-inch slice was taken off vertically from the stable building just inside the wall. At 7 o'clock yesterday morning a man at each jack-screw began to work it, and the wall moved an inch safely. At this time one of the ten men did not work his jack as fast as the rest. The overseers were a little nervous at this, but the wall carried the lazy needle along with the rest. By 10 o'clock the 4,900 square feet of wall were pushed up tight against the open side of the stable, and the whole was perfectly plumb and unshaken. The men in the stables pursued their usual avocations during this performance.—*Extracted from the N. Y. World, Aug. 24th,* 1875.

The Paris Clocks.—M. Leverrier, Director of the Paris Observatory, has just laid before the Prefect of the Seine, a proposal to place all the clocks in Paris in communication with the principal one at the establishment at the head of which he presides. *Galignani* says:—"That piece of mechanism, which is constructed under conditions of almost infallible precision, is placed in the catacombs, so that it may not be subject to the influence of the trepidation felt at the surface of the ground, serves as a regulator to all the other clocks in the Observatory, and gives the time for all the astronomical works carried on there. The perfection of its movement is such that it varies scarcely a fraction of a second in a year. According to the system suggested by M. Leverrier, a telegraphic wire would unite the regulator at the Observatory with the clock at the Luxembourg Palace, facing the Rue de Tournon, and which would in its turn communicate with the Bourse, the Mairies, Palace of Justice, churches, and most of the public buildings. The plan will shortly be submitted to the Muncipal Council."—*The Engineer.*

Centennial Exhibition.—The City of Philadelphia by its liberal appropriation has provided the means for the erection of the Horticultural Hall, which is to remain as one of the permanent buildings of Fairmount Park. It is located on the Lansdowne Terrace, a short distance north of the Main Building and Art Gallery, and has a commanding view of the Schuylkill River and the northwestern portion of the city.

The length of the building is 383 feet; width, 193 feet, and height to the top of the lantern, 72 feet. The main floor is occupied by the central conservatory, 230 by 80 feet, and 55 feet high, surmounted by a lantern 170 feet long, 20 feet wide, and 14 feet high. Running entirely around this conservatory, at a height of 20 feet from the floor, is a gallery 5 feet wide. On the north and south sides of this principal room are four forcing houses for the propagation of young plants, each of them 100 by 30 feet, covered with curved roofs of iron and glass. Dividing the two forcing houses in each of these sides is a vestibule 30 feet square, and at the centre of the east and west ends are similar vestibules, on either side of which are reception rooms.

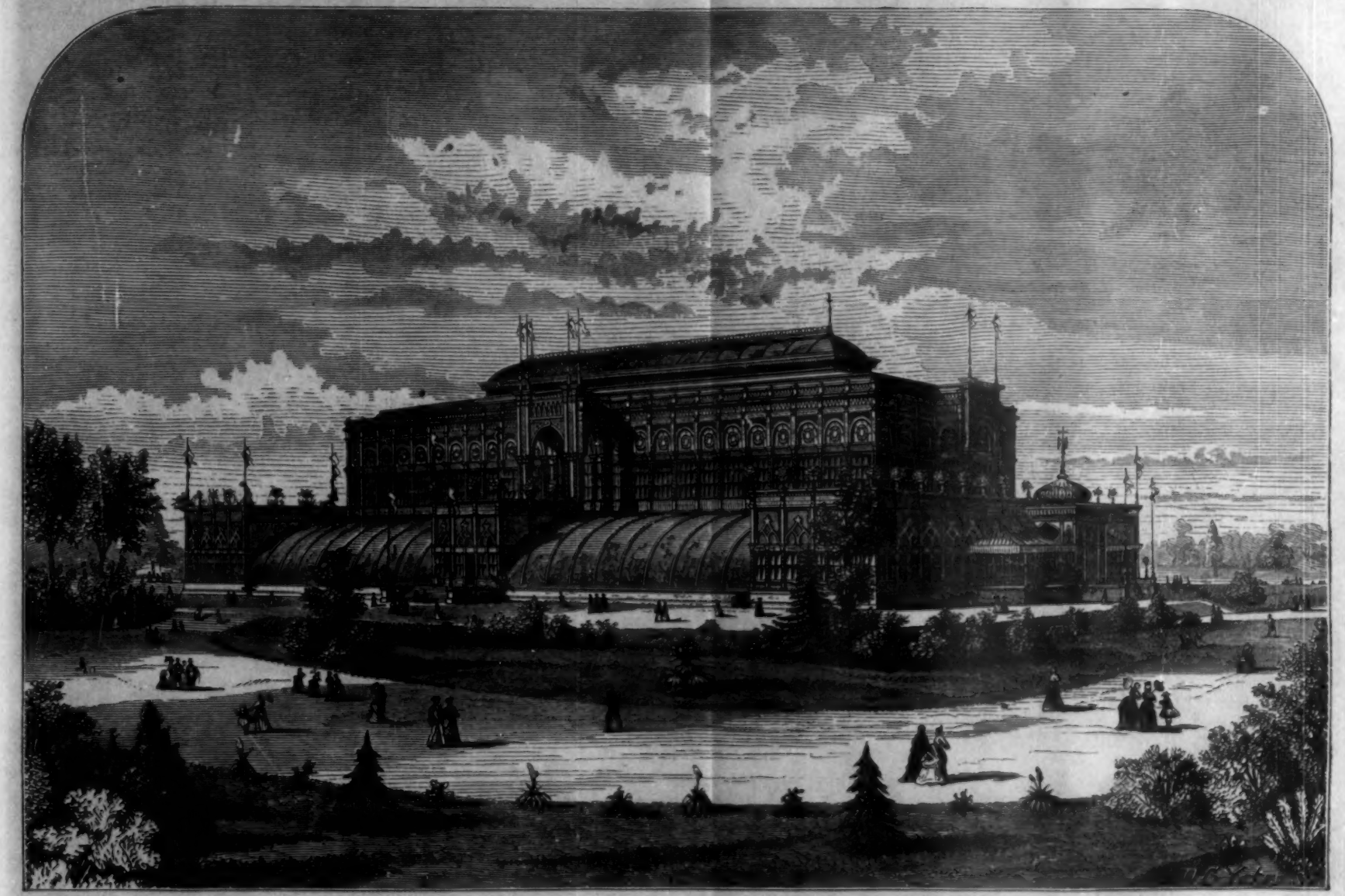
The foundation walls are of rough stone, laid in lime mortar. Those on the exterior are of this material to the ground line, from which to the level of the conservatory floor, they are of pressed brick, with base and copping courses of blue marble.

Running entirely around the conservatory is an inner wall of blue marble and ornamental brickwork, consisting of piers, spaced ten feet apart, and connected by arches at top. Between these piers and the glass walls of the forcing-houses is a corridor ten feet wide.

This inner brick wall reaches to the height of 20 feet, which is the level of the galleries, and from these rise the columns of the second story.

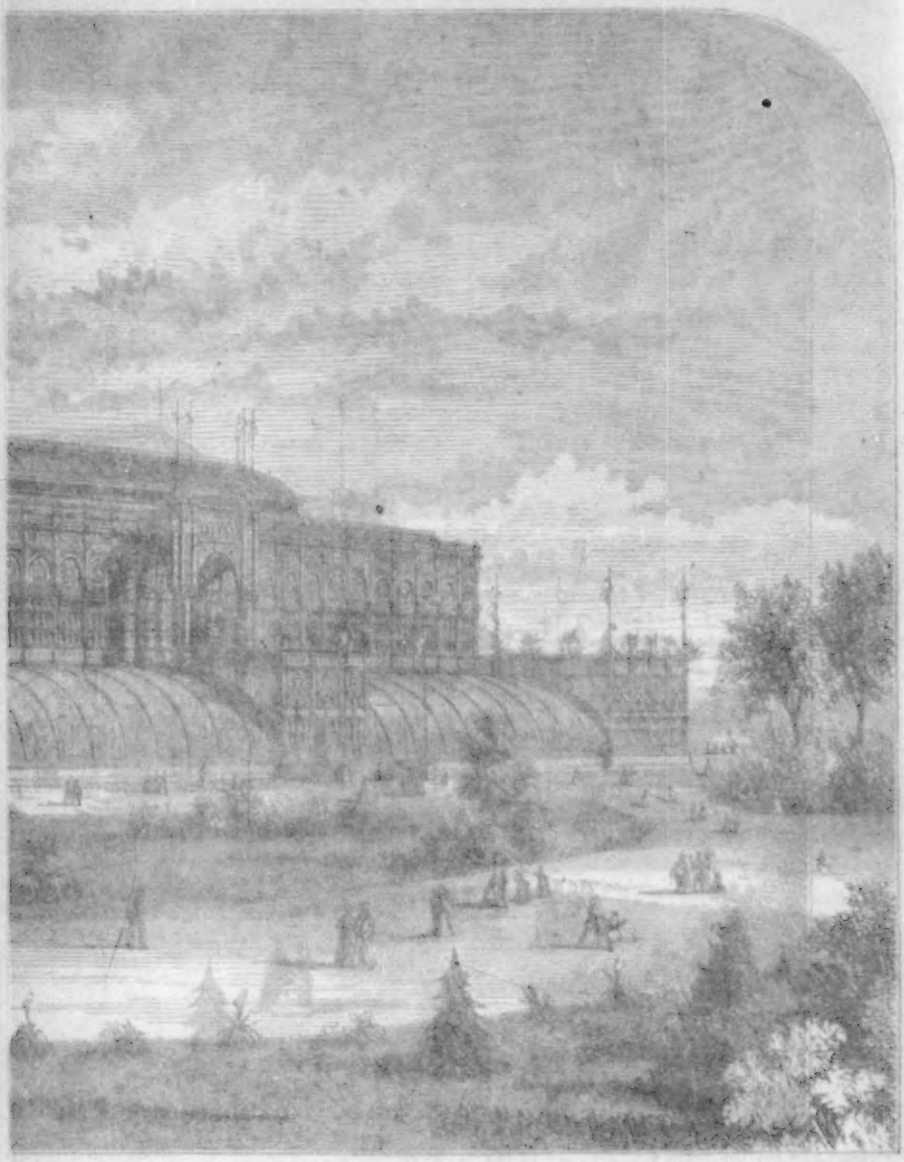
The curved roof of the forcing-houses is formed of nine-inch I beams, bent to shape, and rising from anchor-plates at the floor-level of the forcing-houses, are secured to the corridor columns, continue across the corridors, rest upon and extend 5 ft. beyond the inner wall, forming the floor-beams of the inside and outside galleries.

The anchor-plates at the foot of these beams are secured by tie-rods carried under the floor to the anchor-plates of the corridor columns. Between the beams are cast iron bearers, and resting on these parallel with the main beams, are cast iron ribs, to receive the glass of the roof.



HORTICULTURAL HALL.

INTERNATIONAL EXHIBITION, PHILADELPHIA, 1876.



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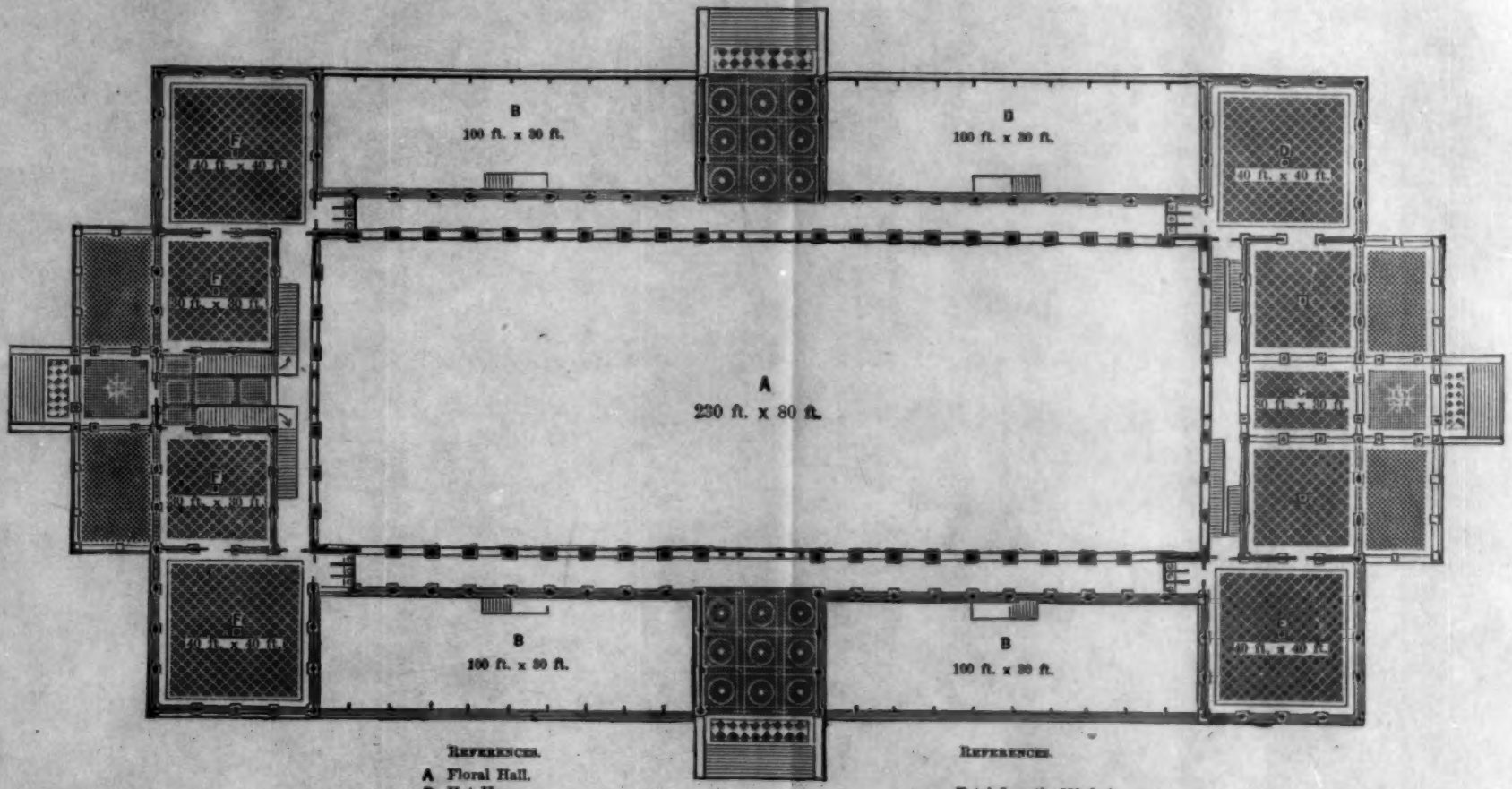
INTERNATIONAL EXHIBITION



REFERENCES.

A Floral Hall.
B Hot Houses.
C Restaurant.
D Gentlemen's Saloon.
E Ladies' Saloon.
F Offices.

REFERENCES.

Total Length, 360 feet.
" Width 160 "
" Height, 72 "

GROUND PLAN OF HORTICULTURAL HALL.

INTERNATIONAL EXHIBITION, PHILADELPHIA, 1876.

A Floral Hall.
B Hot Rooms.
C Restaurant.
D Gentlemen's Saloon.
E Ladies' Saloon.
F Offices.

GROUND PLAN OF HOT
INTERNATIONAL EXHIBITIO

The principal columns are of riveted wrought iron, and in most cases spaced ten feet between centres, and are braced laterally by a system of struts and diagonal ties.

The main roof covering all the portion included within the inner walls, and an additional length of 10 feet over galleries at the ends, 80 by 250 feet in all, is carried on the tops of the columns rising from the top of the inner walls at upper floor-level, except at the ends, where the supporting columns rise directly from the first floor.

The roof trusses have a span of 80 feet, and are spaced 20 feet between centres, except at the middle, where an interval of 30 feet occurs.

Between the roof trusses is a system of lateral bracing similar to that for the columns, and so arranged, that in case of fire, the iron-work would remain standing after all the woodwork was consumed.

The roof of the lantern is of similar construction to the curved roofs of the forcing-houses. The sides are formed of six-inch I beams rising vertically, and curved at the cornice line to form the roof ribs. The cornices around the exterior and interior of the lantern, and the two cornices around the exterior of the conservatory on main roof are of galvanized iron.

The columns around the rooms at the ends of the building are cased in with wood, and the spaces between them, above and below the windows, are filled in with the same material. All the other columns, on the first floor and gallery around the conservatory, are cased in a similar manner.

One of the principal entrances to the grounds is located opposite the eastern front, and on entering the building from this direction, after passing the vestibule, the visitor reaches the general restaurant C, which is 80 feet long by 30 feet wide. At either end of this room are located two saloons, 40 feet square, one, E, for ladies, and the other, D, for gentlemen.

The principal stairway is located at the western end of the building immediately facing the vestibule, and on either side are four offices, F, two of them 30 feet square, and the others 40 feet square.

From the vestibules ornamental stairways lead to the internal galleries of the conservatory, as well as to the four external galleries, each 100 feet long and 10 feet wide, which surmount the roofs of the forcing houses. These external galleries are connected with a grand

promenade, having a superficial area of 1,800 square yards, formed by the roofs of the rooms on the ground floor.

The east and west entrances are approached by flights of blue-marble steps from terraces 80 by 20 feet, in the centre of each of which stands an open kiosque 20 feet in diameter. The angles of the main conservatory are adorned with eight ornamental fountains. The corridors which connect the conservatory with the surrounding rooms open fine vistas in every direction.

In the basement, which is of fire-proof construction, are the kitchen, store-rooms, coal-houses, ash-pits and heating arrangements.

Around the building will be placed other small buildings, graperies, etc., and the surrounding grounds will be arranged for out-door planting, and every facility will be provided for displaying all varieties of useful and ornamental trees and shrubbery, as well as fruit trees.

The work on the Centennial Buildings has progressed as follows:

The roof is on the Horticultural Hall, a portion of the floor is laid, the joiner-work is commenced, and the glazing is in progress. The heating is to be done with hot water, and the apparatus is now being put in.

The grading is being done for the Agricultural Building, and the drainage put in, and the contractor, Mr. Quigley, will soon commence the erection of the superstructure.

The fire-proof floors of the Art Building are being laid, and some plastering done, and the work of completing the dome progressing very well.

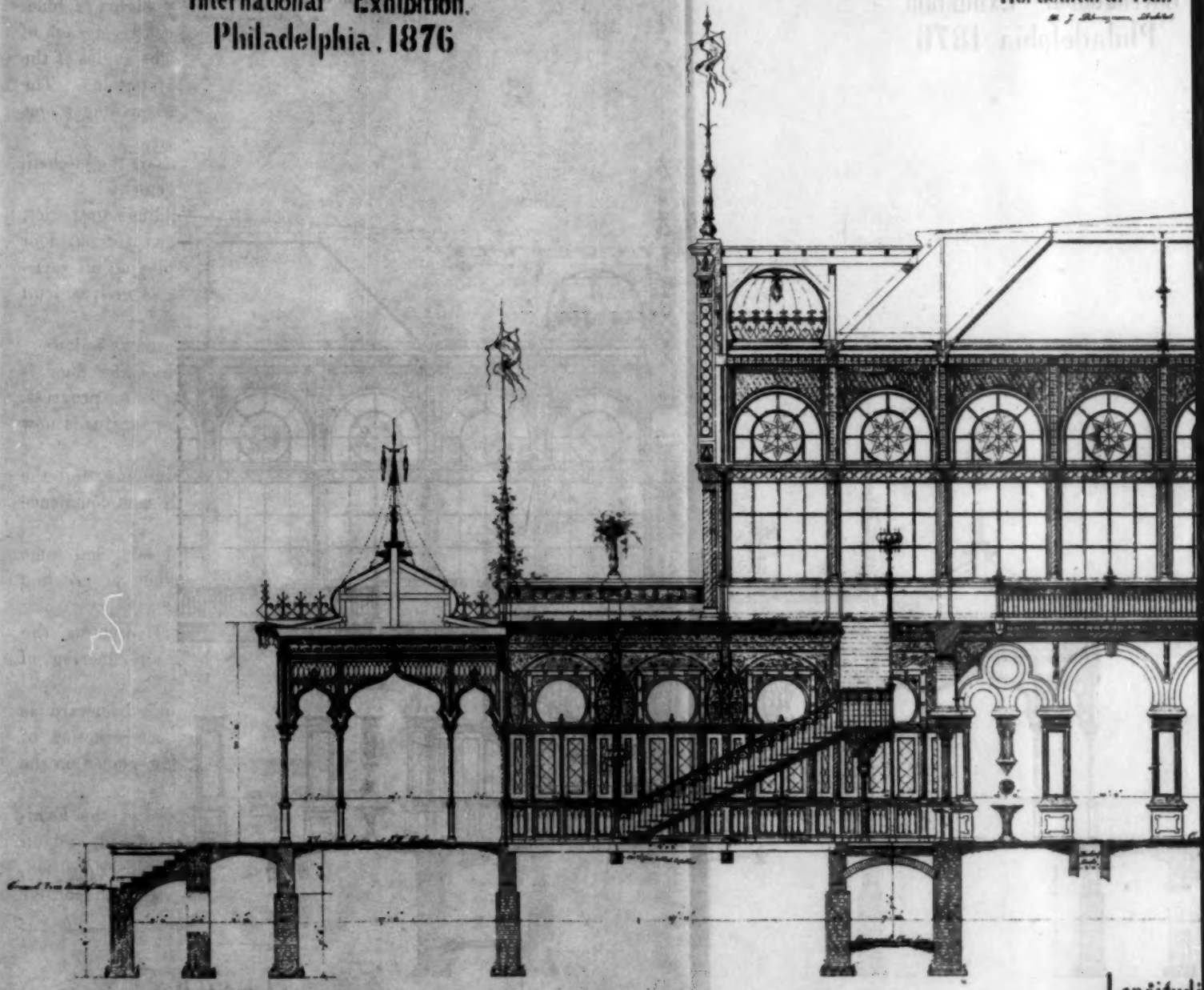
On the Main Exhibition Building, the work of erecting the transept has commenced, and the roofing, glazing and flooring of the other portion is progressing favorably.

The work on the Machinery Building is being pushed forward as usual, the western half being nearly completed, the erection of the transept well under way, and the roof is being placed on the annex.

The walls of the boiler house for the water-works of the Exhibition, are ready for the roof, the stack nearly finished, and on the 26th of August, the stand-pipe was raised and placed in position, immediately north of the Art Building, and on line with the bridge across Lansdowne Valley.

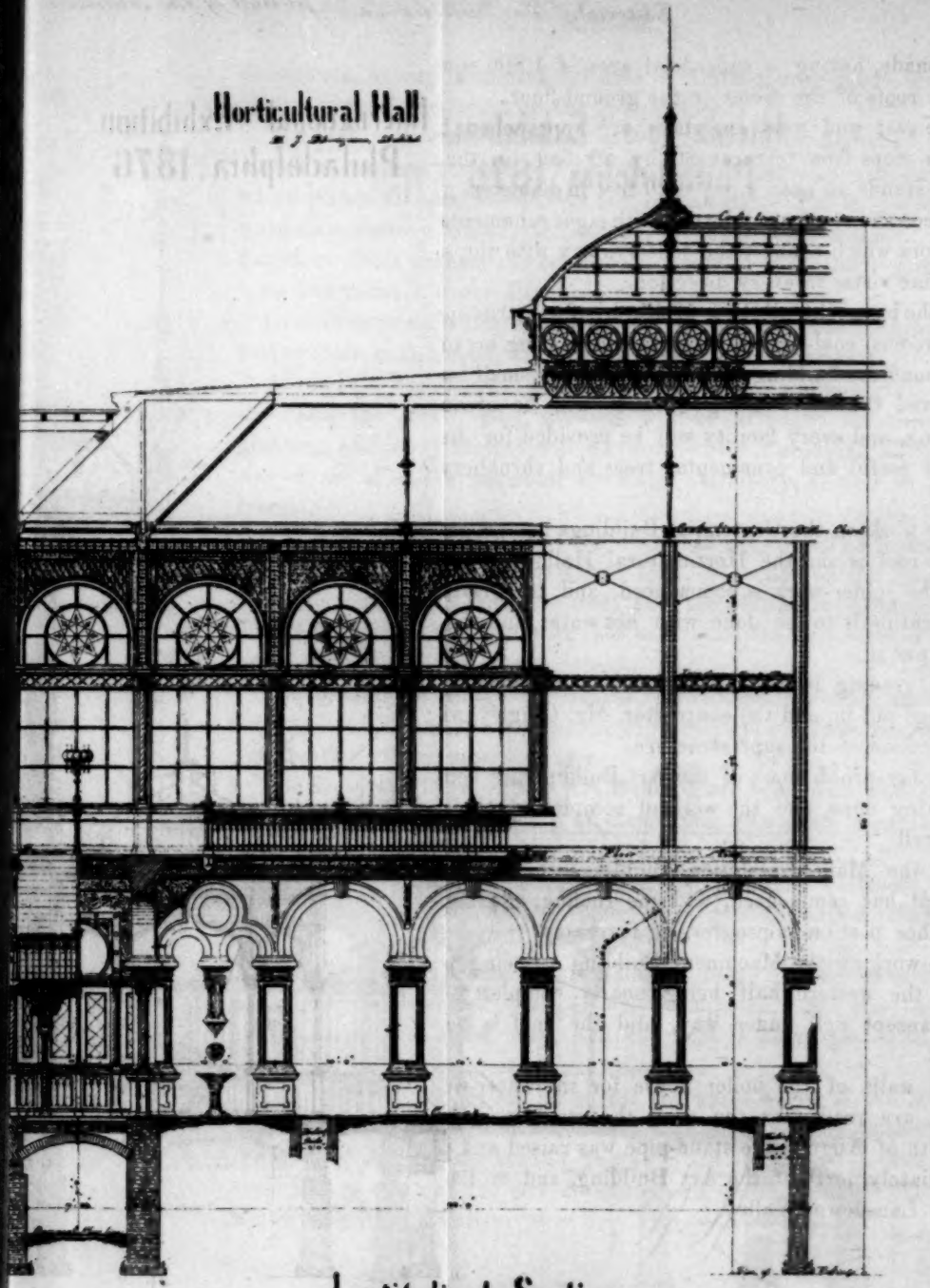
International Exhibition.
Philadelphia, 1876

Horticultural Hall



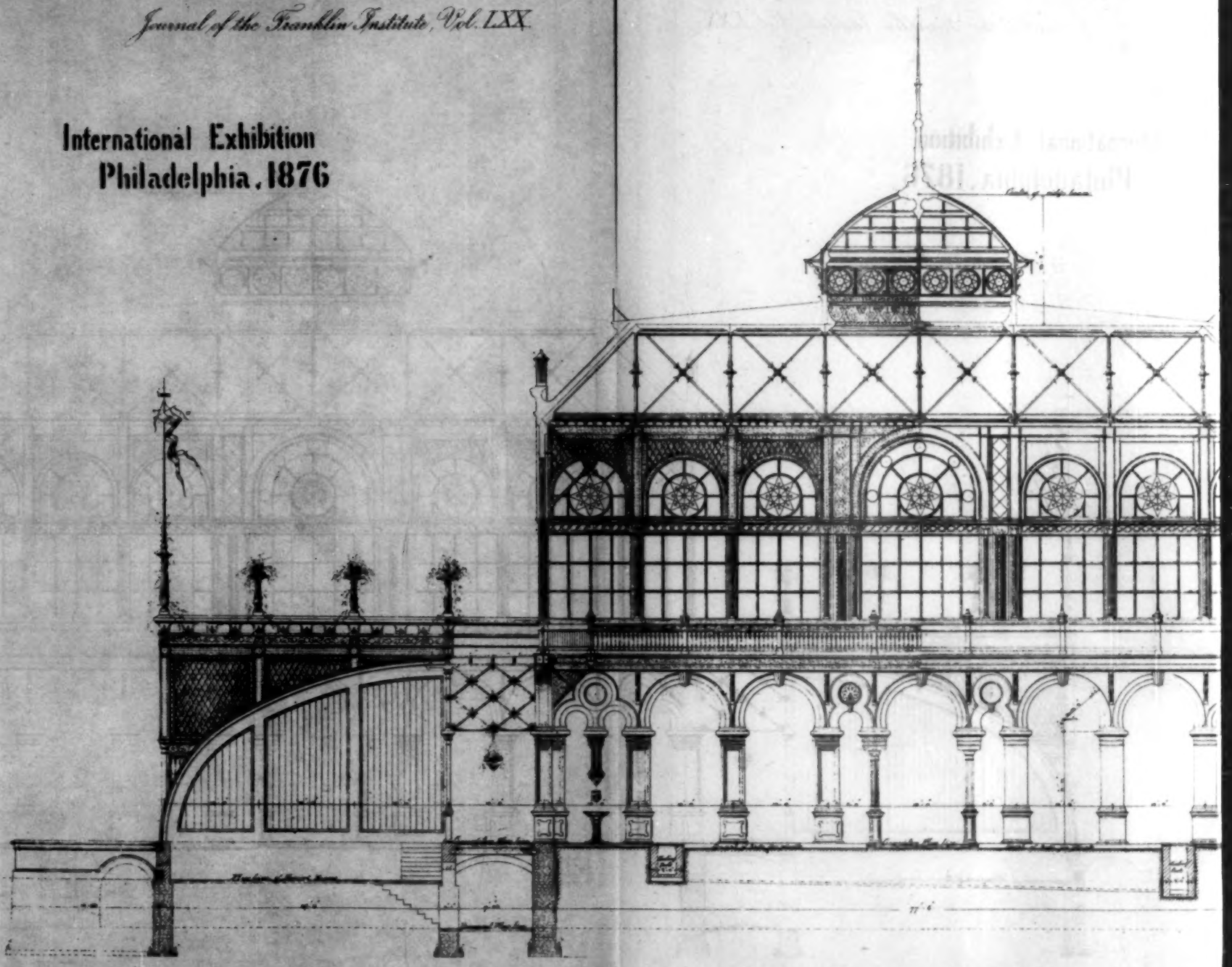
Longitudi

Horticultural Hall

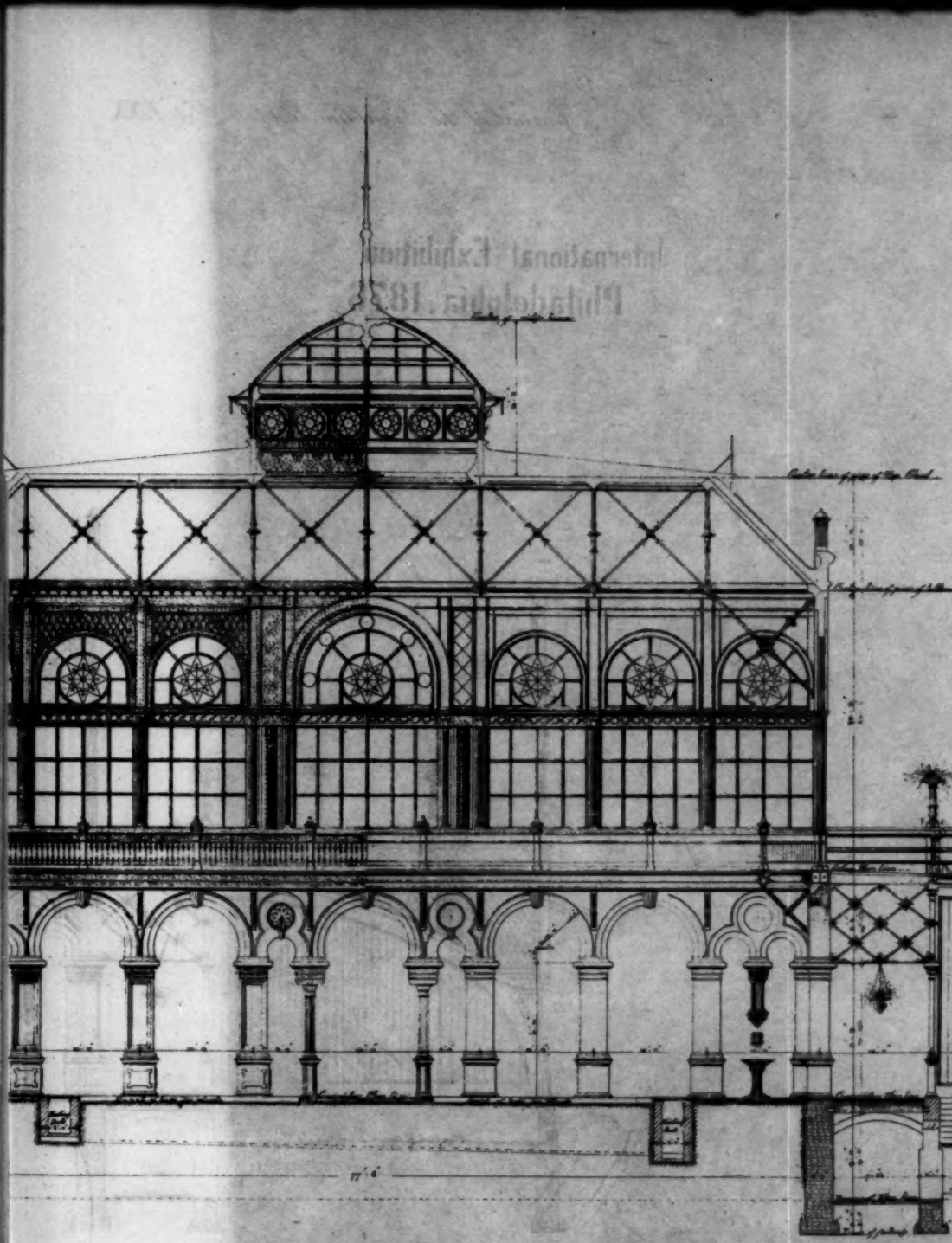


Longitudinal Section

International Exhibition
Philadelphia, 1876

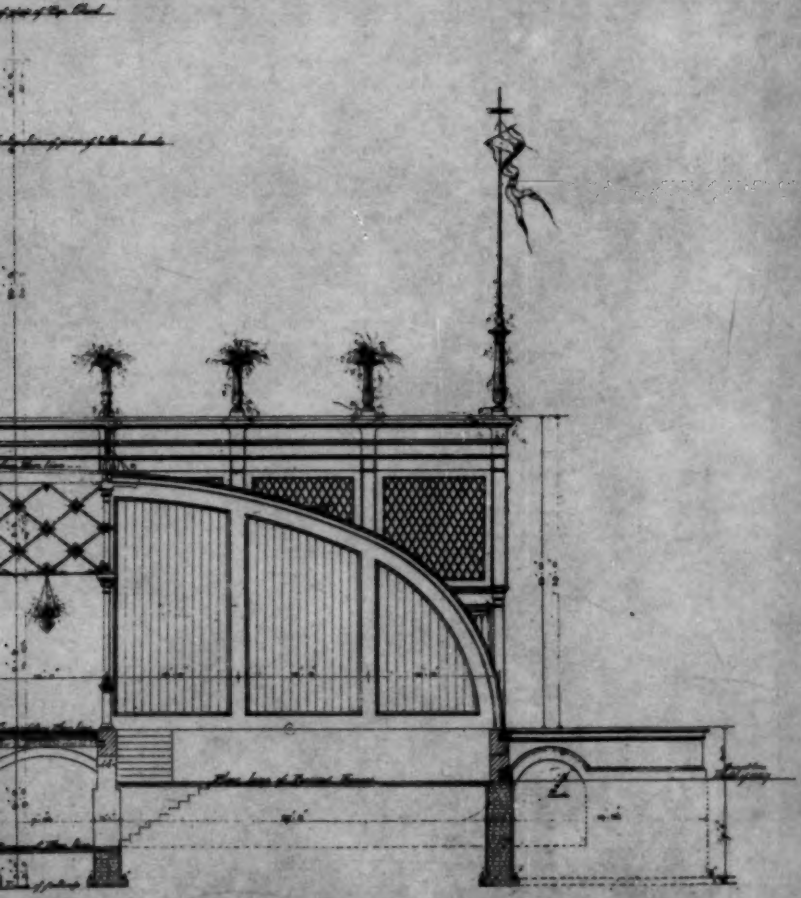


Transverse Section



Transverse Section

Horticultural Hall



Transverse Section

The erection of the framing of the United States Government Building is commenced, and the foundations of that for the British Commission are laid. There seems no reason why the buildings should not be ready for the reception of goods at the time proposed.

K.

Manipulation of Blast Furnaces.—In the August number of the JOURNAL, a notice was inserted relative to the extraordinary feat of banking up a furnace for two hundred and seventeen days, and its successful recovery at the expiration of that time.

We have now to record the partial re-lining of a furnace without blowing out or accident. From a paper read before the American Institute of Mining Engineers, May, 1875, by Mr. Frank Firmstone, and published in the *Engineering and Mining Journal* of August 21st, is extracted the following:

At the distance of 5 or 6 feet below the tunnel head, on two opposite sides, the lining was completely gone for a height of about 4 feet, below which it increased gradually in thickness, being 9 inches thick about 3 feet lower down. Elsewhere at about the same level, the brick were not entirely gone, but were in some places only 2 or 3 inches thick, being still sufficient, however, to sustain the upper part, where the brick being above the level of the stock, were not at all worn.

The furnace was blown down, so that when we cast and closed the tuyeres, about 7 A.M., on December 8th, the top of the stock was about 24 feet below the filling-plates. The walls were quite hot, and a good deal of gas was given for several hours after the tuyeres were closed. The hopper and bell were thrown into the furnace, and were covered by filling several charges of cold stock over them, which at once greatly cooled off the top of the furnace. A wrought iron pipe, 30 inches in diameter, in five sections, each 6 feet long, was then put down, and made to stand upright, as nearly as possible in the centre of the furnace. Around this, we filled a double charge of coal, taking care to keep it up next the pipe, and let it get thinner as it got to the walls. This was covered with about 2 feet of fine ore, leaving the first joint in the pipe entirely uncovered. We were now ready to put in our scaffold to get at the brickwork. The scaffold was 10 feet in diameter, and was suspended from two stout poles (which reached across the top of the furnace, and rested on two trestles, about 6 feet high), by four chains and four pair of differential blocks,

whereby it could easily be raised and lowered as might be required. The frame of the scaffold, which had been well painted and sanded, was put together around the pipe in the centre of the furnace, and was floored over with 2 inch plank, leaving a hole 3 feet 4 inches square in the middle. Four pieces of 3x4 scantling, 16 inches long, were nailed upright at the four corners of this opening, and by nailing sheet iron from post to post, were formed into a square chimney surrounding the pipe. By this arrangement, most of the gas was drawn off through the central pipe, which got pretty hot soon after it was put in, and at the same time the strong ascending current, in the space between the square chimney and the pipe, carried off any gas which might leak through the fine ore, and brought a stream of fresh air down past the faces of the men as they worked at bricklaying.

These arrangements were completed about 7 P.M., when the night shift of bricklayers came on.

We at first tried to build up the holes, intending to wedge up the top brick, which were still perfect, on the new work, and then cut out and rebuild the thin places, a little at a time. We soon found that we could not get base enough for this, and determined to take out all the old work, from the top down, until we had from 6 inches to 9 inches to start on, and then rebuild, closing each course as we went.

Taking out these bricks was the hardest part of the job. They were, many of them, too hot to touch without hand-leathers, and the loam-filling between the front and back lining made a very thick dust.

After the top courses were out, we had to set props to prevent the lower bricks from falling in a mass. All the bricks were out about 4 A.M., on the 9th, and at 6.30 A.M., the day shift of bricklayers began to rebuild, finishing about 10 P.M.

Cast iron angle plates, 1 inch thick, were built in every joint, to cover the brick and prevent rapid wear in the future.

When the masonry was done, we lowered the scaffold to the bottom, knocked off the chimney, and took the bolts out of the lower joint in the pipe. After the chimney was removed, there was a slight smell of gas at the bottom, but the time spent in taking out the bolts was so short, that no one got sick from it.

The scaffold and the upper part of the pipe were then hoisted out, leaving the lower section in the furnace, and the rest of the night was spent in sending down the pipe, etc., and clearing away for put-

ting in the new bell and hopper. This was accomplished, and the blast put on by 3 P.M., of the 10th.

The furnace started without trouble, and although she slipped and worked irregularly for some weeks, she finally came to work very well, and the new part of the lining promises to last indefinitely.

On Meta-Brom-Toluol.—Dr. E. A. Grete.—As a matter of exceeding interest to some of our readers, we extract the following from the "*Chemical News*," July 30th, 1875, where it appears as the title of a paper in Justus Liebig's Annalen der Chemie, of June 25th, 1875. We can scarcely express our regret that the paper itself is not at our disposal for reproduction in its entirety.—This paper treats of the preparation of meta-brom-toluol; of meta-brom-sulphitoluol and its calcium, strontium, magnesium, copper, lead, and potassium compounds; and concludes that the sulphi-acid produced by the reaction of the meta-brom-toluol with fuming sulphuric acid, and corresponding to salicylic acid, belongs to the ortho series, and is consequently meta-brom-ortho-sulphi-toluol. The author further examines mono-nitro-meta-brom-toluol, mono-amido-meta-brom-toluol, meta-brom-amido-toluol sulphate, nitrate, hydrochlorate, and oxalate of meta-brom-toluydin; meta-brom-acettoluydin; dinitro-meta-brom-toluol; diamido-meta-brom-toluol, with its sulphate, hydrochlorate, nitrate and oxalate.

Toluole (C_{14} H_8) is one of a large number of hydro-carbons derived from coal oil, which have defined chemical composition. [Benzole (C_{12} H_6) is better known in popular language, and is the next combination above it in order of evaporation.] These hydro-carbons make regular combinations with bromine, chlorine, etc., which again become radicals and are acted upon in various ways and make further combination with other chemical substances, in endless permutation. Meta-brom-toluole is composed of bromine, carbon and hydrogen; and this remarkable collocation of words becomes intelligible to the professional chemist and informs him how completely the investigation has been made.

The Value of a Dozen.—As the derivation from the French douzaine implies, it is generally presumed that a dozen implies twelve things, but in the Staffordshire potteries, and in the earthenware trade (queensware in Philadelphia, crockery in other places) a dozen to this day represents that number of any special article which can be offered at a fixed price. That is, the price is fixed and the number to the

dozen varies. For instance, the pitchers (which are called "jugs" in the trade) are sold as 2, 3, 4, 6, 9, 12, 18, 24, 30, 36 pieces to each dozen, the price for a dozen being constant. The ordinary pitcher, holding a quart, is *a twelve* or twelve to the dozen, while a pint pitcher is twenty-four to the dozen, and is so-called when dealing in that size. Few of the articles of the trade are sold in dozens of twelve, plates being almost the only ones, and some of them are sold at sixty to the dozen. Beside these curiosities in figures, the potters have peculiar names, muffins, twiflers, etc., that make up a trade language of itself. The quantities for dozens are, we think, *yet* preserved in the wholesale, or package trade.

The Annual Consumption of Iron per Inhabitant in the United States.—We are favored by an article compiled by Mr. J. M. Swank, Secretary American Iron and Steel Association, from which it appears that in 1870, the consumption per capita was 171 pounds.

This result was reached from the returns of the United States census. Mr. Swank has endeavored to deduce from the data in his possession, the consumption in the United States in 1872, and he estimates the quantity for that year to be 223 pounds per inhabitant. Mr. Swank further deduces from English statistics, that the quantity of iron per inhabitant of the United Kingdom, was 220 pounds for the same year, 1872.

Contrasting the above quantities with those given in the report of the Hon. Abram S. Hewitt, U. S. Commissioner to the Paris Exposition, of 1867, namely: 189 pounds in England; 100 pounds in America; 69½ pounds in France, we have a basis of estimate of the magnitude and growth of the manufacture of iron.

The estimates are as follows, in tons of 2000 pounds:

Gross production of Iron and Steel in the U. S. in 1872,	4,829,303
Deduct Exported Iron and Steel,	306,680
Total consumption,	4,522,623
To 40,000,000 of inhabitants.	
Gross production of Iron and Steel (in tons of 2240 pounds) in the United Kingdom, in 1872,	6,741,929
Deduct Exportation, Manufactured or otherwise,	3,603,537
Total consumption,	3,138,392
To 31,800,000 of inhabitants.	

Civil and Mechanical Engineering.

ON THE STRENGTH OF PULLEY-ARMS.

The correct method of proportioning the arms of pulleys, wheels, etc., when the arms, rim, and hub are all cast in one piece, or when they are all so firmly fastened together as to be equivalent to being made in one piece, is from the following facts evidently not understood by writers on mechanics. Rankine, in his "Mills and Millwork," page 555, gives formulæ for calculating the dimensions of pulley-arms, and remarks in regard to the above case, that "the greatest bending moment is exerted on each arm at two points, close to the rim and close to the boss respectively," and shows, by his formula, that the arms should have the same strength at each of these points. Other eminent writers declare that the case is the same as the one, common in machinery, of a beam built in at one end, and loaded at the other *free end*, and the shape usually given to pulley-arms seems to show that this is the common belief, since they are almost invariably made strongest near the hub or boss, and weakest near the rim.

On account of this contradiction of authorities, and believing that neither of the above was the true theory, the writer was led to solve the problem for himself, and the main steps of the solution with its result are here reproduced.

First in order to discuss the stresses acting on the different parts of a loaded beam, we must determine the shape assumed by the *elastic curve*, being the axis of the beam when slightly bent by the forces acting on it. We will therefore start with the general formula for the elastic curve of prismatic beams, acted upon by vertical forces.

$$\text{(1)} \qquad \text{WE}\frac{d^2y}{dx^2} = \text{M}.^*$$

in which W is the amount of inertia of the section of the beam, E the coefficient of elasticity, and M the resultant moment of all forces

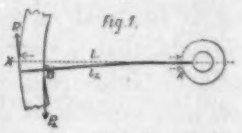
* See Weisbach's Mechanics, Part I, ¶ 223.

acting on the section at that point of the elastic curve whose co-ordinates are x and y. The axis of X coincides with the axis of the beam when not loaded, the beam being straight in that condition, and the origin of co-ordinates is at the point of support. Suppose the beam discussed to be built in at one end, and acted upon by two forces, P_1 and P_2, at distances l_1 and l_2 from the point of support; then M would be equal to $P_1(l_1 - x) + P_2(l_2 - x)$, and after substituting this value, the two integrations of formula (1) give the following formulæ:

$$\frac{dy}{dx} = \tan a = \frac{P_1(2l_1x - x^2) + P_2(2_2lx - x^2)}{2WE} \tag{2}$$

$$y = \frac{P_1(3l_1x^2 - x^3) + P_2(3l_2x^2 - x^3)}{6WE} \tag{3}$$

in which a is the angle of the curve at the point xy, with the axis of X. These formulæ apply to all cases which fulfill the above conditions, and it will be seen from Fig. 1 that pulley-arms fulfill those conditions, for the reason that they may be considered as built in at the hub or boss, A, and acted upon at the rim by the forces P_1 and P_2. P_1 acts in an opposite direction to P_2, and is just sufficient to maintain the arm in a radial direction at the point B, or where the arm meets the rim. Call the co-ordinates of this point l_2 and y_2, and the angle a_2, and we have the following relation:



$$\tan a_2 = \frac{y_2}{l_2 + r} \tag{4}$$

r being the radius of the hub. Referring equations (2) and (3) to the point B, by substituting l_2 for x and then substituting the values of $\tan a_2$ and y_2, thus found in equation (4) and reducing, we have

$$P_1 = -P_2 \frac{l_2(l_2 + 3r)}{3l_1l_2 - 2l_2^2 + 6l_1r - 3l_2r} \tag{5}$$

Substituting this value of P_1 in the above value of the moment M, and then putting $M = 0$, and solving for x, in order to find what point of the arm is acted upon by no bending moment, we find

$$x_0 = \frac{l_2(2l_2 + 3r)}{3(l_2 + 2r)} \tag{6}$$

Suppose r to be any multiple of l_2, as ml_2, then if we substitute this

value of r in equation (6), we find

$$x_0 = \frac{3m+2}{3(2m+1)} l_2 \tag{7}$$

and if we put

$m = \infty$,	we find	. . .	$x_0 = \frac{1}{2} l_2$.
$m = 1$,	"	. . .	$x_0 = \frac{5}{9} l_2$.
$m = 1\text{-}2$,	"	. . .	$x_0 = \frac{7}{12} l_2$.
$m = 1\text{-}4$,	"	. . .	$x_0 = \frac{11}{18} l_2$.
$m = 1\text{-}10$,	"	. . .	$x_0 = \frac{23}{36} l_2$.
$m = 0$,	"	. . .	$x_0 = \frac{2}{3} l_2$.

We see from this that as m, and therefore r, decreases, x_0 rapidly approaches the value 2-3 l_2, and in the ordinary cases in practice m is so small that it may be neglected without appreciable error. We find therefore that the point of the arm which is acted upon by no bending force is two-thirds the length of the arm from the hub. Fig. 2 represents an arm constructed on this principle. The force transmitted by the pulley tends to shear the arm at the point C, while one-third of the force tends to break the arm at the rim, and two-thirds to break it at the hub. The arm should therefore be twice as strong at the hub as at the rim. It should be, moreover, stronger at the hub than Rankine's formula requires, in the ratio of $\frac{2}{3}$ to $\frac{1}{2}$, but may be weaker than the ordinary method requires in the ratio of $\frac{2}{3}$ to 1.

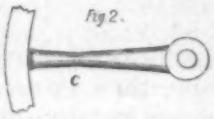


Fig 2.

This result also shows the best place to connect the arms when the hub and rim are made separately, for if two-thirds of the arm is cast with the hub, and one-third with the rim, the joint need not be made stiff, for even if it is a hinge joint, the arm will not be weakened.

We have found, in the table under equation (7), that if $m = \infty$, the point x_0 comes in the middle of the arm, and the bending moment at the rim and hub would therefore be the same in this case, and the arm would receive the same proportions from our formulæ as from Rankine's. But in putting $m = \infty$, we assume that the hub is infinitely large compared with the length of the arm, which is equivalent to supposing it a beam fixed between two parallel walls, which tend to slide past each other, as in Fig. 3. Rankine has therefore supposed that pulley-arms are acted upon in the same way as the beam of Fig. 3, the error of which is discovered above.

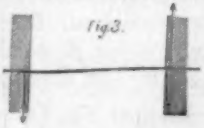


Fig 3.

Another interesting fact shown by the table under formula (7) is, that while the radius of the hub as compared with the arm diminishes from infinity to zero, the point of no moment moves from the middle of the arm to a point at a distance from the rim, of one-third the length of the arm, and is in no case outside of these two points.

A. K. MANSFIELD, M.E.

Cordova, Argentine Republic, S. A., July 5, 1875.

[This discussion of the strength of pulley-arms is a very valuable addition to the application of mathematical study in mechanical construction. It must not be overlooked, however, in the consideration of the strength of the arm of any fly-wheel or pulley, that not only the strains resulting from work or changes of speed will enter, but also any strains existing in the metal of the arm itself must be allowed for. It is necessary that the thickness of metal in the arm should bear such relation to the masses or thickness of the hub or rim, as will allow nearly uniform cooling of all the parts. The founder can, by judicious uncovering of disproportioned rims, hubs, or arms, measurably overcome the irregularities of cooling and consequent shrinkage; but a pulley, or more especially a fly-wheel with arms abundantly strong by calculation for all possible working service, can, with difficulty, be got out of the sand without hot or cold cracks in arms or hub. And if an apparently sound casting is had, there will exist in the arms strains of shrinkage which will seriously impair its strength.

These strains are frequently so great that pulleys may, and do fail or break upon, and sometimes after service, and even, at times, fly unexpectedly in the workshop. The greatest variation of conditions are these two cases: one of a fly-wheel where the weight is required in the rim, and the other of a pulley where any thickness of rim which can be cast is superabundant to carry the adhesion of a belt. It may be said roughly that in the case of the fly-wheel, an oval arm whose thickness shall not be less than one-third that of the least dimension of the rim, and whose sectional area at the point of junction shall not be less than one-fourth that of the rim; and in the case of the pulley, an arm whose thickness shall not be greater than twice that of the rim, and whose sectional area shall not be greater than one-third the rim, will suffice. That with these proportions of arms, and with hubs to correspond, the care of the founder can insure castings *measurably* free from strains. A full discussion and scale resulting from it, of the proportions of arms of pulleys with straight arms and solid hubs, embracing all the conditions of light pulley and heavy balance or gear wheel, from the founder's point of view, would supplement this note of Mr. Mansfield very satisfactorily.]—ED. JOUR.

EXPERIMENTS MADE AT THE MARE ISLAND NAVY-YARD, CALIFORNIA, WITH DIFFERENT SCREWS APPLIED TO THE UNITED STATES STEAM LAUNCH NO. 4, TO ASCERTAIN THEIR RELATIVE PROPELLING EFFICIENCY.

By Chief Engineer B. F. Isherwood, U. S. N.

[Continued from Vol. lxx, page 116.]

Experiments made to ascertain the dynamometrical resistances to dragging, of the experimental screws A, B, C, D, E, F, and H, of the United States steam-launch No. 4, when it was towed by the United States screw-steamer Monterey, with its screws disconnected from its engines, and revolving freely by the pressure of the water on the forward side of their blades, and held stationary in different positions.

The following experiments are the only ones of their kind of which the writer has knowledge. They supply, in part, a great desideratum in marine steam-engineering, and show the loss of speed sustained by a steamship when under sail alone, consequent on the dragging of its screw through the water in different stationary positions, and when revolving freely by the pressure of the water on the forward surface of their blades. They also show the comparative resistance of screws of different kinds, with different proportions and number of blades, under the above conditions.

The screws employed in these experiments were screws A, B, C, D, E, F, and H, of the United States steam-launch No. 4, embracing all, with exception of screw G, that were used in the experiments made with that launch and detailed in the immediately preceding report.

During the experiments about to be described, the launch was at a less draught of water than during those referred to, and had the following dimensions and proportions in the water:

Length, in feet, on load water-line, from forward edge of rabbet of stem to after side of stern-post,	.	54·40
Extreme breadth, in feet, on load water-line,	.	11·88
Depth, in feet, of hull from load water-line to lower edge of rabbet of keel,	forward	2·160
	mean	2·891
	aft	3·622

Table No. 9, containing the data and results of an experiment made with the machinery of the United States steam-launch No. 4, with screw G, to ascertain the evaporative efficiency of the boiler with anthracite, and the cost of the indicated and dynamometrical horse power in pounds' weight of steam and of fuel consumed per hour. (During this experiment, the vessel was secured to the wharf of the Mare Island navy-yard, California, with the stern raised six inches and held suspended by a floating crane.)

Date of commencing the experiment.....9.23 A. M., March 30th, 1870.	
VESSEL.	
Vessel's draught of water, in feet and inches.....{forward.	3 7
{mean...	3 11½
{aft.....	4 4
TOTAL QUANTITIES.	
Duration of the experiment, in consecutive hours and minutes.....	9·18
Number of double strokes of engines' pistons, and of revolutions of the screw.....	65,844·
Number of pounds of anthracite consumed.....	1,910·
Number of pounds of refuse from the anthracite in ash, clinker, etc.....	310·
Number of pounds of combustible consumed.....	1,600·
Per centum of the anthracite in refuse of ash, clinker, etc.....	16·23
Cubic feet of feed-water pumped into the boiler from the tank.....	220·212
Pounds of feed-water pumped into the boiler from the tank.....	13,728·439
RATE OF COMBUSTION.	
Pounds of anthracite consumed per hour.....	205·376
Pounds of combustible consumed per hour.....	172·043
Pounds of anthracite consumed per hour, per square foot of grate surface.	24·655
Pounds of combustible consumed per hour, per square foot of grate surface.	20·653
Pounds of combustible consumed per hour, per square foot of heating surface.....	0·927
TEMPERATURES.	
Temperature, in degrees Fahrenheit, of the external atmosphere.....	61·
Temperature, in degrees Fahrenheit, of the engine and boiler room.....	88·
Temperature, in degrees Fahrenheit, of the bay water.....	60·
Temperature, in degrees Fahrenheit, of the feed-water in the tank.....	58·
Temperature, in degrees Fahrenheit, of the feed-water entering the boiler.	125·
ENGINES.	
Number of double strokes made per minute by the engines' pistons.....	118·
Steam-pressure in boilers in pounds per square inch above the atmosphere.	92·
Position of the throttle-valve.....	wide open.
Fraction of the stroke of the piston completed when the steam was cut off.	0·858
Thrust of the screw in pounds, per dynamometer.....	858.55
Height of the barometer in inches of mercury.....	29·38
STEAM PRESSURES IN CYLINDERS, PER INDICATOR.	
In pounds per square inch above zero at commencement of stroke of pistons.....	104·2
In pounds per square inch above zero at point of cutting off the steam....	98·7
In pounds per square inch above zero at end of stroke of pistons.....	81·2
In pounds per square inch above zero against the pistons during their stroke.....	21·1
Mean gross effective pressure on pistons, in pounds per square inch.....	80·9
Mean total pressure on pistons, in pounds per square inch.....	102·0
Mean net pressure on pistons, in pounds per square inch.....	78·9

POWER.	
Absolute:	
Gross effective indicated horse-powers developed by the engines	27·221
Total horse-powers developed by the engines	34·320
Net horse-powers developed by the engines	26·549
Dynamometrical horse-powers developed by the engines	23·025
Economic:	
Pounds of anthracite consumed per hour, per gross effective indicated horse-power	7·545
Pounds of anthracite consumed per hour, per total horse-power	5·984
Pounds of anthracite consumed per hour, per net horse-power	7·736
Pounds of anthracite consumed per hour, per dynamometrical horse-power	8·920
Pounds of combustible consumed per hour, per gross effective indicated horse power	6·720
Pounds of combustible consumed per hour, per total horse-power	5·014
Pounds of combustible consumed per hour, per net horse-power	6·480
Pounds of combustible consumed per hour, per dynamometrical horse-power	7·472
Pounds of feed-water consumed per hour, per gross effective horse-power	54·229
Pounds of feed-water consumed per hour, per total horse-power	43·012
Pounds of feed-water consumed per hour, per net horse-power	55·604
Pounds of feed-water consumed per hour, per dynamometrical horse-power	64·112
VAPORIZATION.	
Total:	
Total number of pounds of water that would have been vaporized in the boiler, had it been supplied at the temperature of 100 degrees Fahrenheit, and vaporized under the atmospheric pressure of 29·92 inches of mercury	13,876·906
Total number of pounds of water that would have been vaporized in the boiler, had it been supplied at the temperature of 212 degrees Fahrenheit, and vaporized under the atmospheric pressure of 29·92 inches of mercury	15,499·255
Economic:	
Pounds of water vaporized from 100° Fahrenheit by one pound of anthracite	7·265
Pounds of water vaporized from 100° Fahrenheit by one pound of combustible	8·673
Pounds of water vaporized from 212° Fahrenheit by one pound of anthracite	8·115
Pounds of water vaporized from 212° Fahrenheit by one pound of combustible	9·067
CONDENSATION.	
Pounds of steam discharged from the cylinders into the atmosphere, calculated from the pressure of the steam at the end of the stroke of the pistons	8,452·090
Pounds of steam condensed in the boiler and cylinders to furnish the heat transmuted into the total power developed by the engines, according to Joule's equivalent	930·696
Sum of the above two quantities	9,382·786
Per centum of the steam evaporated in the boiler, condensed in the boiler and cylinders to furnish the heat transmuted into the total power developed by the engines	6·78
Per centum of the steam evaporated in the boiler not accounted for by the indicator	31·65
Difference, due to all causes, between the weight of feed-water pumped into the boiler, according to the tank, and the weight of steam discharged from the cylinders into the atmosphere at the end of the stroke of the pistons, per indicator, expressed in per centum of the feed-water	38·43

Load-draught, in feet, of water from the bottom of the keel,	forward	2·66
	mean	3·62
	aft	4·58
Area, in square feet, of the greatest immersed transverse section,		21·83
Area, in square feet, of the immersed external surface of the hull proper, exclusive of keel and rudder,		571·
Area, in square feet, of the immersed external surface of the hull, inclusive of keel (100·8 square feet) and rudder (13·2 square feet,)		685·
Displacement, (cubic feet),		693·117
Displacement, (tons),		19 842
Ratio of the area of the greatest immersed transverse section to the area of its circumscribing parallelogram,		0·6356
Ratio of the displacement to its circumscribing parallelopipedon,		0·3710

The remaining dimensions of the launch can be obtained from the immediately preceding report. Its hull, during the experiments about to be described, had 0·265 foot draught of water less than during the experiments on the propelling efficiency of the screws, with, of course, a corresponding decrease in the area of the greatest immersed transverse section, in the area of the immersed external surface, and in the displacement. The greatest immersed transverse section and the immersed solid of the hull were also sharper than with the greater draught of water. The resistance of the hull must, therefore, have been less. It was in fact $\left(\frac{707-631\times100}{707}=\right)10\frac{3}{4}$ per centum less at the speed of seven geographical miles per hour, as measured by the dynamometer.

MANNER OF MAKING THE EXPERIMENTS.

The screw-steamer Monterey, by which the steam-launch No. 4 was towed, is a small tug attached to the Mare-Island navy-yard. On the deck of this vessel, at the stern, the bed-plate of a very sensitive dynamometer was bolted, consisting of a single horizontal lever, one end of which bore against a vertical steel knife-edge, by means of a steel bush, the knife-edge being firmly secured to the bed-plate.

The other end was articulated to a spiral spring, the opposite extremity of which, in its turn, was also articulated to the bed-plate. At one-tenth of the distance between the points at which the lever was secured to the bed-plate, measured from the end opposite that to which the spring was attached, was a vertical steel knife-edge bearing against a steel bush. To the extremities of this knife-edge a small steel loop U-shaped, was articulated, and to this loop the tow-line from the steam-launch was fastened. The leverage of the spring against the tow-line was exactly ten to one. The weight of the lever was supported on delicate brass friction-rollers, polished, and moving on polished brass ways. Great precaution was thus used to make the friction of the dynamometer as little as possible, and it was reduced to the extent that one-fourth of a pound tension on the spring was sufficient to give movement to the unloaded instrument.

A scale, graduated to pounds by careful trial for its whole length, was attached to the base-plate of the spring, and the opposite end of the spring carried a pencil, which traced on a moving sheet of paper the curve of tensions described by the combined movement of the pencil and paper, and measured by the scale. The paper was wound around a light polished brass cylinder of eight inches diameter, the steel axle of which, at each end, was supported in brass bearings secured to the bed-plate of the dynamometer. This cylinder received a rotary movement from the screw-shaft of the vessel by means of two shafts at right angles to each other, the first being horizontal and lying just above the deck, the second being vertical and connecting the first, by my means of mitre-gearing, with the screw-shaft. The vertical shaft received its movement from the screw-shaft by means of an endless worm and wheel, and the cylinder received its movement from the horizontal shaft by similar mechanism. The dynamometer-diagram, thus traced, was sufficiently long for a single run of the vessel, so that it was continuous from one end of the base to the other.

The base used was the one employed in the previous experiments on the propelling efficiencies of the screws of steam-launch No. 4 already referred to. It was a straight line 8,950 feet long, in smooth water, and under the lee of the high ground of Mare Island.

The tow-line was a small cord, just strong enough to sustain the maximum tension without breaking, and 170 feet in length between the vessels. It was attached, by means of a bridle, to the bows of

the launch about 18 inches above the deck, so that the towing strain was exactly in the vertical plane of the keel. The screw of the Monterey had but a very small slip when towing the launch, so that any water thus thrown backward lost its movement within a very short distance and exercised no effect upon the following launch. The strain on the dynamometer exerted by the tow-line alone, at different angles of inclination from the vertical, was experimentally ascertained and deducted from the strain on the dynamometer when towing the launch with the same angle of inclination of the tow-line.

Throughout these experiments both vessels remained at exactly the same draught of water, and during each trial the steam-pressure in the Monterey's boiler, the position of the throttle-valve of its engine, and all other conditions, were maintained as nearly constant as possible.

The speed of the launch was ascertained both by the shore-marks and by the Berthon tube, in the same manner as described by the preceding experiments on the propelling efficiency of the screws. The number of revolutions made by the screw, when revolving freely by the pressure of the water on the forward surface of their blades, was ascertained by a counter, in the manner described for the experiments already referred to. The same persons were employed in both sets of experiments, and were perfectly expert in making them. Nothing that could conduce to extreme accuracy was omitted. During these trials, the screw-shaft was disconnected from the crank-shaft of the launch's engines, so that in revolving it had only the friction of its journals and collars to overcome. Its stuffing-box, at the inboard end of the dead-wood, was packed barely sufficiently tight to prevent water-leakage.

The mean tension on the tow-line was obtained by dividing the straight base of each dynamometer-diagram into abscissæ of half an inch length, and erecting therefrom ordinates at right angles to the base, and cutting the curve of tensions. The mean length of these ordinates, measured by the scale of the spring, and multiplied by the leverage of the latter, gives the mean tension on the tow-line. The base-line of the diagram is described by revolving the cylinder without tension on the spring.

Each trial consisted of six runs over the base, three in each direction, and were made with the screws in the following positions, namely:

First. With screw A, 11 inches long in the direction of the axis, two-bladed, and of 5·136 feet pitch, six runs were made with the blades in a vertical position immediately behind the stern-post of the vessel, the latter having the speed of seven geographical miles per hour, as nearly as could be obtained. Then six runs were made with the blades at right angles to their former position—that is horizontally or square across the vessel—at as nearly the speed of seven geographical miles per hour as could be obtained. Finally, the screw being allowed to freely revolve, six runs were made at the speed of seven geographical miles per hour, as nearly as could be obtained; after which six runs were made at each of the speeds of $6\frac{1}{2}$, 6, and $5\frac{1}{2}$, geographical miles per hour, as nearly as could be obtained.

Second. With screw B, which was exactly the same as screw A, except that its length was $8\frac{3}{8}$ inches in the direction of the axis instead of 11 inches, precisely the same set of trials was made as with screw A.

Third. With screw C, which was exactly the same as screw A, except that its length was $5\frac{1}{2}$ inches in the direction of the axis, precisely the same set of trials was made as with screw A.

Fourth. With screw D, which was exactly the same as screw A, except that its length was $3\frac{1}{8}$ inches in the direction of the axis, precisely the same set of trials was made as with screw A.

Fifth. With screw E, which was composed of four blades equispaced around the axis, the length of each blade in the direction of the axis being $5\frac{1}{2}$ inches, and the pitch, surface, and diameter the same as those of screw A, six runs were made with two blades in the vertical position immediately behind the stern-post of the vessel, and the other two blades in the horizontal position or square across the vessel, the vessel's speed being 7 geographical miles per hour, as nearly as could be obtained. Then six runs were made with the blades of the screw standing at the angle, of 45 degrees with the horizon, the speed of the vessel being 7 geographical miles per hour, as nearly as could be obtained. Finally, the screw being allowed to revolve freely, six runs were made at the speed of 7 geographical miles per hour, as nearly as could be obtained; after which six runs were made at each of the speeds of $6\frac{1}{2}$, 6, and $5\frac{1}{2}$ geographical miles per hour, as nearly as could be obtained.

Sixth. With screw F, which was 11 inches long in the direction of its axis, and composed of four blades arranged in two pairs—the

blades of each pair being directly opposite each other—and one pair placed immediately behind the other, so that when viewed in projection on a plane at right angles to the axis, the screw appeared to be two-bladed, six runs were made with the blades in a vertical position immediately behind the stern-post of the vessel, the latter having the speed of 7 geographical miles per hour as nearly as could be obtained. Then six runs were made with the blades at right angles to their former position—that is, horizontally or square across the vessel—at as nearly the speed of 7 geographical miles as could be obtained. Finally, the screw being allowed to revolve freely, six runs were made at the speed of 7 geographical miles per hour as nearly as could be obtained; after which six runs were made at each of the speeds of 6½, 6, and 5½ geographical miles per hour, as nearly as could be obtained. Screw F is also known as the Mangin or duplex screw; and its pitch, surface, and diameter, were the same as those of screw A.

Seventh. With screw H, which was a three-bladed Griffith screw of 11 inches extreme length, and a pitch that expanded from 6⅞ feet to 7⅛ feet, the diameter being the same as that of screw A, six runs were made with one blade vertical *below* the shaft—that is, immediately behind the stern-post of the vessel—and the remaining two blades *above* the shaft at angles of 60 degrees from the vertical, the vessel's speed being 7 geographical miles per hour as nearly as could be obtained. Then six runs were made with one blade vertical *above* the shaft—that is immediately behind the stern-post of the vessel—and the remaining two blades *below* the shaft at angles of 60 degrees from the vertical, the vessel's speed being 7 geographical miles per hour as nearly as could be obtained. Then, six runs were made with one blade horizontal—that is, square across the vessel on one side of the stern-post—and the remaining two blades on the other side of the stern-post at angles of 60 degrees from the vertical. Finally, the screw being allowed to revolve freely, six runs were made at the speed of 7 geographical miles per hour as nearly as could be obtained; after which six runs were made at each of the speeds of 6½, 6, and 5½ geographical miles per hour, as nearly as could be obtained.

RESULTS.

Of the resistance of the hull, per se, that is, its resistance without any screw attached—Steam-launch No. 4 was towed at all speeds from 5½ to 7½ geographical miles per hour, as nearly as could be

obtained, increasing by one-fourth of a geographical mile per hour. Six runs were made at each speed, and the mean taken of the experimental speeds and of the corresponding dynamometer-diagrams. A comparison of these means with each other showed that, within the above limits, the resistance of the hull was in the ratio of the square of its speed; the extreme variation from this law on either side of the mean being only 2 per centum of the mean, and was as often greatest for the low speeds as for the high. *At the speed of 7 geographical miles per hour the resistance of the hull, as given by the mean of all the dynamometer-diagrams taken at all the different speeds, and reduced in the above proportion, is* 631 *pounds.*

When the steam-launch, instead of being towed, was propelled by its own screws, the resistance of its hull at the speed of 7 geographical miles per hour was 707 pounds; the difference in the two cases is consequently (707—631=) 76 pounds, or $\left(\frac{76 \times 100}{707} =\right) 10\frac{3}{4}$ per centum of the larger quantity. A part of this is due to the vessel's less draught of water when it was towed than when it was propelled by its own screws. In the former case its greatest immersed transverse section was 21·83 square feet; in the latter case 24·98 square feet; difference, $\left(\frac{24{\cdot}98 - 21{\cdot}83 \times 100}{24{\cdot}98} =\right) 12{\cdot}61$ per centum of the larger quantity. In the latter case the area of the immersed external surface of the hull was 717 square feet; in the former case 685 square feet; difference, $\left(\frac{717 - 685 \times 100}{717} =\right) 4{\cdot}46$ per centum of the larger quantity. In the latter case the displacement was 23·3053 tons; in the former case, 19·8420 tons; difference, $\left(\frac{23{\cdot}3053 - 19{\cdot}8420 \times 100}{23{\cdot}3053} =\right) 14{\cdot}86$ per centum of the larger quantity. The mean of the three $\left(\frac{12{\cdot}61 + 4{\cdot}46 + 14{\cdot}86}{3} =\right) 10{\cdot}64$ per centum, is almost the exact experimental difference of the resistance in the two cases.

Results with screw D.—This screw was two-bladed, and had the least surface of any employed in these trials; it is therefore convenient to first ascertain its results. The principal portion of its pro-

jected area on a plane at right angles to the axis is nearly masked or covered by the stern-post of the vessel when the two blades are placed vertically behind it.

When the blades of screw D held stationary in the vertical position immediately behind the stern-post of the vessel, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour was 657 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remained for the resistance of the screw, *per se*, 26 pounds. Consequently, the screw, with its blades in the vertical position, increased the vessel's resistance $\left(\frac{26 \times 100}{631} =\right)$ 4·12 per centum, and decreased its speed ($\sqrt{631} : \sqrt{657} :: 7 : 7{\cdot}1428$; and $7{\cdot}1428 - 7 =$) 0·1428 geographical miles per hour, or $\left(\frac{0{\cdot}1428 \times 100}{7{\cdot}1428} =\right)$ 2 per centum.

With the blades of screw D held stationary in the horizontal position, square across the vessel, the aggregate resistance of the vessel and screw, at the speed of 7 geographical miles per hour, was 756 pounds; deducting from which the 631 pounds due to the resistance of the vessel, there remains for the resistance of the screw, *per se*, 125 pounds. Consequently, the screw, with its blades in the horizontal position, increased the vessel's resistance $\left(\frac{125 \times 100}{631} =\right)$ 19·81 per centum, and decreased its speed ($\sqrt{631} : \sqrt{756} :: 7 : 7.6620$ and $7{\cdot}6620 - 7. =$) 0·6620 geographical mile per hour, or $\left(\frac{0{\cdot}6620 \times 100}{7{\cdot}6620} =\right)$ 8·64 per centum.

From the above it appears that screw D, when its blades were held in the horizontal position, square across the vessel, had $\left(\frac{125}{26} =\right)$ 4·808 times the resistance it had when its blades where held in the vertical position, immediately behind the vessel's stern-post.

When screw D was allowed to revolve freely by the pressure of the water of the forward face of its blades, it made 757 revolutions per geographical mile, which number was not affected by the speed of the vessel, but remained constant for all speeds from $5\frac{1}{2}$ to 7 geographical miles per hour. The axial speed of the screw was conse-

quently $\left(\frac{6086 - 5{\cdot}136 \times 757 \times 100}{6086} =\right)$ 36·12 per centum less than the speed of the vessel, and when the latter was 7 geographical miles per hour, the screw was dragged bodily through the water at the speed of 2·528 geographical miles per hour. The revolutions of this screw were not uniform, the rotary speed fell off greatly as the blades came into the vertical position behind the stern-post of the vessel, at which point there was a decided hesitation in passing, after which the rotary speed increased. That speed appeared uniform for a considerable portion of the half revolution, the falling off occurring as the blades became masked by the stern-post, owing to their excessive narrowness in projecting on a plane at right angles to their axis.

With the vessel at the speed of seven geographical miles per hour and screw D revolving freely, the aggregate resistance of vessel and screw was 685 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 54 pounds. Consequently, the screw, when revolving freely, increased the vessel's resistance $\left(\frac{54 \times 100}{631} =\right)$ 8·56 per centum; and decreased its speed ($\sqrt{631} : \sqrt{685} :: 7 : 7{\cdot}2934$; and 7·2934 $-7{\cdot} =$) 0·2934 geographical mile per hour, or $\left(\frac{0{\cdot}2934 \times 100}{7{\cdot}2934} =\right)$ 4·02 per centum.

When a two-bladed screw has so small a fraction of the pitch as screw D, namely, 0·1014, whereby its blades are nearly masked by the vessel's stern-post, it appears that the resistance due to the screw when revolving freely is 2 per centum of the resistance of the vessel, *per se*, more than when it is held stationary with its blades behind the stern-post in the vertical position; but 3 per centum less than when it is held stationary with its blades in the horizontal position, square across the vessel. The resistance of the revolving screw in this case is greater, proportionally, than when a larger fraction of the screw is used, owing to its making a less number of revolutions per mile in consequence of the falling off of its rotary speed as its blades pass the stern-post.

Results with screw C.—This screw was two bladed, and had the next greatest surface to screw D. Their surfaces compared as $3\frac{1}{8}$ to $5\frac{1}{2}$ and were of exactly the same kind. A considerable portion of the

surface of screw C projected on each side of the vessel's stern-post when the blades were in the vertical position.

With the blades of screw C held stationary in the vertical position immediately behind the stern-post of the vessel, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour, was 721 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remain for the resistance of the screw, *per se*, 90 pounds. Consequently, the screw, with its blades in the vertical position increased the vessel's resistance $\left(\frac{90 \times 100}{631} =\right)$ 14·26 per centum; and decreased the speed ($\sqrt{631} : \sqrt{721} :: 7 : 7{\cdot}4826$; and $7{\cdot}4826 - 7 =$) 0·4826 geographical mile per hour, or $\left(\frac{0{\cdot}4826 \times 100}{7{\cdot}4826} =\right)$ 6·45 per centum.

With the blades of screw C held stationary in the horizontal position, square across the vessel, the aggregate resistance of the vessel and screw at the speed of 7 geographical miles per hour was 851 pounds, deducting from which the 631 pounds due to the resistance of the vessel, there remains for the resistance of the screw, *per se*, 220 pounds. Consequently, the screw with it blades in the horizontal position, iucreased the vessel's resistance $\left(\frac{220 \times 100}{631} =\right)$ 34·86 per centum; and decreased its speed ($\sqrt{631} : \sqrt{851} :: 7 : 8{\cdot}1292$ and $8{\cdot}1292 - 7 =$) 1·1292 geographical miles per hour, or $\left(\frac{1292 \times 100}{8{\cdot}1292} =\right)$ 13·89 per centum.

From the above, it appears that screw C, when its blades were held in the horizontal position, square across the vessel, had $\left(\frac{220}{90} =\right)$ 2·444 times the resistance it had when its blades were held in the vertical position, immediately behind the vessel's stern-post.

When screw C was allowed to revolve freely by the pressure of the water on the forward face of its blades, it made 921 revolutions per geographical mile, which number was not affected by the speed of the vessel, but remained constant for all speeds from 5½ to 7 geographical miles per hour. The axial speed of the screw was consequently

$\left(\frac{6086 - 5{\cdot}136 \times 921 \times 100}{6086} =\right)$ 22·28 per centum less than the speed of the vessel, and when the latter was 7 geographical miles per hour, the screw was dragged bodily through the water at the speed of 1·559 geographical miles per hour. The revolutions of this screw were uniform, and there was no appearance of hesitation when the blades came into the vertical position behind the stern-post of the vessel.

With the vessel at the speed of 7 geographical miles per hour, and screw C revolving freely, the aggregate resistance of vessel and screw was 698 pounds; deducting from which the 631 pounds due to the resistance of the vessel, there remain for the screw, *per se*, 67 pounds. Consequently, the screw, when revolving freely, increased the vessel's resistance $\left(\frac{67 \times 100}{631} =\right)$ 10·62 per centum; and decreased its speed ($\sqrt{631} : \sqrt{698} :: 7 : 7{\cdot}3623$; and $7{\cdot}3623 - 7. =$) 0·3623 geographical mile per hour, or $\left(\frac{0{\cdot}3623 \times 100}{7{\cdot}3623} =\right)$ 4·92 per centum.

From the foregoing it appears that the resistance due to screw C, when revolving freely, is 3·64 per centum of the resistance of the vessel, *per se*, less than where it is held stationary with its blades behind the stern-post in the vertical position; and 24·24 per centum less than when it is held stationary with its blades in the horizontal position, square across the vessel.

(To be continued.)

Erratum.—Page 113, line 4, for steam read stern. The method of raising *steam*, and keeping it up by a floating crane, suggested by this typographical error, is quite happy in obviating all danger from boiler explosions. An originality for this invention is claimed by the compositor of the JOURNAL, and all are warned that a patent cannot be obtained by any other individual.

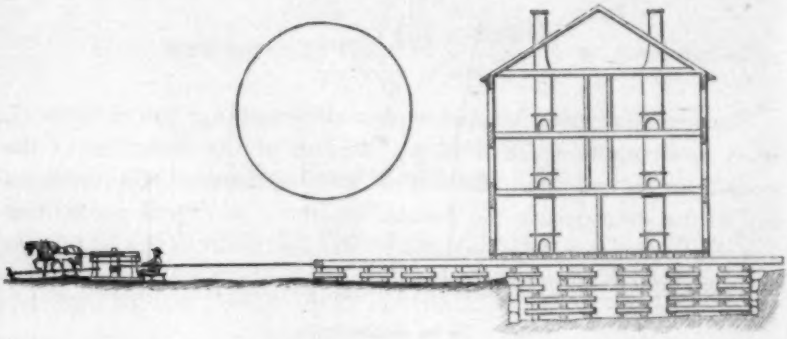
MOVING BRICK HOUSES.

By Charles S. Close.

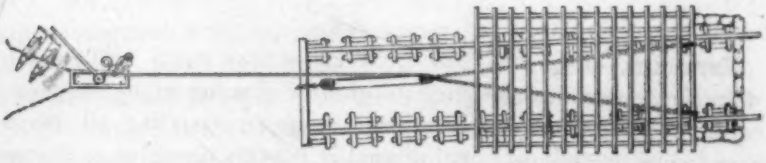
It may interest some of the readers of the Journal to have a short description of the manner of moving brick houses from one location to another, as recently effected in this city.

A good and substantial three-story dwelling, measuring 30 feet by 18 feet on the plan, and about 30 feet height of walls to the eaves, was erected on the farm of Henry Myers, in the southern part of the district of Southwark, about twenty years ago. This building (with a portion of the farm) was recently sold to the Frankford & Southwark Railroad Company. When the company commenced to build their southern terminus depot, they concluded to move the dwelling house to the line of Fifth Street, a distance of nearly four hundred feet.

Sectional Elevation.



Sectional Plan.



The first step was to break holes through the side (9 in.) walls on the level of the under side of the ground floor, between every other pair of floor joists, which were about 16 inches, centre to centre, or 13 inches apart. Through these holes rough yellow pine timbers 12

inches square by about 25 feet long, were inserted, which were thus 2 feet 8 inches, centre to centre. These timbers were brought up into contact with the floor, and keys were driven on top of them to support the side walls. The front and back walls were carried by needles, and two timbers parallel to the cross timbers, were laid in line of the walls, and after blocking up on top of these timbers, the needles were removed. The ends of all the timbers were then braced apart by blocking fitted between each pair, until the whole formed a cradle.

The lifting was effected by jack-screws near the end of each timber, about two feet outside of the walls, fifteen (three nests or sets of five each) on each side. The jack-screws were set tight by one man alone, to ensure equality of strain; after which a man was allotted to each five screws. At the blow of a hammer each man gave a quarter turn to each of his five screws. The raising was two feet lift, and the jack-screws were fleeted three times. A spare screw was applied to the end of the timber, and the working screw relieved, blocking inserted, and then the shortened screw replaced.

A pile of blocking was laid in the cellar and other blocking built on the ground outside and leveled up with cross wedges, and two skids 12 inches square by 60 feet long were laid on the blocking. The cradle was then dropped upon the skids. The upper skid surface and the under side of the cradle were coated with soap. The skids were irregularly placed to suit the convenience of ground or direction, only it was necessary that the distance apart should be such that the chain attachment should work between them.

A long chain sling, ($\frac{3}{4}$ in. or $\frac{7}{8}$ in.), was attached to the last or back timber, so that a pull was placed on all the braces, and the cradle was firmly clamped together. The bight of the chain came under the cradle and was brought to the front and was there hooked into a tackle consisting of a pair of three-fold blocks with 8 inch manilla rope. The second block was hooked to a cross timber which formed a cross-head to the skids, and prevented them being drawn on end. The hauling part of the rope led off to the crab which had a 12 feet bar, to which were attached two horses. The usual spuds held the crab.

The actual moving was at the rate of 2 feet per minute. The whole moving did not occupy two days, but some delay occurred in taking up the stone walls of the old cellar and building the new cellar walls with the material. The course, or path of the moving, was by no means straight, other foundations and irregularities of ground

interfered, and an S path of 50 feet or more deviation was followed. The final position of the house, as left after removal *by the crab*, was within one-fourth an inch of the exact place it should occupy, and this deviation was easily rectified by a jack-screw. The dropping upon the new walls was the reverse of the lifting, except that the screws were applied inside the cellar instead of outside as before.

The great excellence of this operation was its mechanical roughness and simplicity. Everything was convenient, ready and adapted for its work, and seven workmen, well-drilled, all practical laboring men.

DESCRIPTION OF THE PERNOT FURNACE.

Translated from the French of M. Armengaud.

By William F. Durfee, Engineer.

(Continued from Vol. lxx, page 103.)

Works at Fraisans.

M. Vallette, agent of the Franche-Comte Forge Company, assisted at the trials made from the 30th of May to the 4th of June, of the Fraisans pig irons, (used alone or mixed with one-third or two-thirds of gray Rochette pig,) for obtaining puddled iron of ordinary quality. The coal used was of the same quality as in the preceding trials, and consisted of a mixture of small semi-bituminous coal and coal dust in the proportion of one to five. The table (given page 101) shows the results obtained by M. Vallette.

We will remark, that in these several trials, the mixture of the pig iron was constantly changed so as to observe the action of the furnace in the different cases which occur in practice. Thus for the five charges in the first day's work of the furnace, Fraisans No. 3 pig was used alone and produced a granulated puddle-bar. The first three charges of the second day were composed of Fraisans No. 5 pig and gave as a result ordinary puddle-bar; the ninth, seventeenth, nineteenth, and twenty-third charges were composed of one-half

Fraisans No. 3 pig and one-half of gray Rochette pig, and the puddle-bar was granular. The eighteenth was composed of gray Rochette pig alone, the twenty-fourth of one-third Fraisans and two-thirds gray Rochette.

Finally, the twenty-fifth, thirtieth, and thirty-third charges consisted of two-thirds Fraisans No. 3, and one-third gray Rochette, and the thirty-first and thirty-second of the same as the first, of Fraisans No. 3 alone. All these mixtures produced granulated puddle-bar. The coal used for lighting up on the 1st of June was 2·05 tons, which make the total consumed 28·05 tons. To produce one ton (2240 lbs.) of iron, the materials required are as follows:

Pig iron, . . .	2304 lbs. = 1·029 tons.	
Coal, ...	2050 " = 0·915 "	not including lighting up.
Hammer-slag, .	179 " = 0·08 "	
Iron ore, . .	166 " = 0·074 "	

It is easy to deduce from the foregoing the net cost per ton of the iron obtained.

Blast Furnaces at Montlucon.

MM. Boigues, Rambourg & Co. have also tried their irons in the Pernot furnace. The trials were made in the presence of M. Bonnamy, their engineer and superintendent of manufacture. They had sent to St. Chamond on the 4th of June, 1874, 10915 lbs. = 4·88 tons of very silicious common gray pig iron, which was divided into six charges, five of 1984·5 lbs. and one of 992·25 lbs. There was used 1610 lbs. of iron ore and 88 lbs. of hammer-slag. There was produced in one day and five hours (17 hours) 10315 lbs. = 4·6 tons of granulated puddle bar, the consumption of coal being 9208 lbs. = 4·11 tons, its quality being the same as that heretofore used. The production of puddled bar in 12 hours was 7280 lbs. = 3·25 tons; it would have been 7909 lbs. = 3·34 tons, but for the last charge, for which the Montlucon pig was taken to complete it to 1984·5 lbs.

A ton (2240 lbs.) of puddled bar was produced from 2370 lbs. of gray silicious pig, and 336 lbs. of iron ore, with an expenditure of 2000 lbs. of coal; results which are regarded with great satisfaction when compared with those obtained from the same materials in the common furnace.

The following table shows the time required for working the several charges, and their respective product:

1st charge.	Time	1 h. 55 m.	Weight	1984·5 lbs.	Product	1883 lbs.
2d "	"	2 h. 15 m.	"	1984·5 "	"	1852 "
3d "	"	2 h. 20 m.	"	1984·5 "	"	1872 "
4th "	"	2 h. 35 m.	"	1984·5 "	"	1874 "
5th "	"	2 h. 25 m.	"	1984·5 "	"	1886 "
6th "	"	2 h. 15 m.	"	992·25	"	948 "
				10915 lbs.		10315 lbs.
				or 4·88 tons.		or 4 6 tons.

To complete these statistics which are without doubt interesting to owners of forges in general, we will now give accounts of other trials made with pig irons of different kinds, sent to St. Chamond by the northern works and from those of Belgium.

Ougree Forges.

These works sent one lot of 12480 lbs. = 5·57 tons of white pig iron, and another lot of 27893 lbs. = 12·44 tons of a mixture composed of two-thirds of Ougree spiegel, and one-third of white pig. The following is the result of the working of the first lot:

Ougree White Iron.

1874.	Time.		Charges.	Weight of Iron.	Hammer-Slag.	Coal.	Common Puddle bar.
	Hrs.	Min.		Lbs.	Lbs.	Lbs.	Lbs.
July 15th.	10		5	10,922	684	7,198	9,312
July 17th.	2	30	1	1,558	132	1,343	2,434
Totals.	12	30	6	12,480	816	8,541	11,746 or 5·24 tons.

The above result corresponds to a production of 11276 lbs. = 5 tons in twelve hours. The coal used was the same kind as that in the trial of the Franche-Comte irons. This experiment made in the presence of M. Ghys, engineer of the Ougree Co., resulted in the production of one ton (2240 lbs.) of puddle bar, at an expenditure of 2381·14 lbs. of white pig iron, 135 lbs. of hammer-slag, and 1630 lbs. of coal.

MIXTURE OF ⅗ OUGREE SPIEGEL AND ⅕ WHITE IRON.

July. 1874.	Days' Work.		Charges.	Pig Iron.	Iron Ore.	Hammer-Slag.	Coal.	Puddled Iron.	Quality.
	Hrs.	Min.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
15	5	30	2	3,969		220	3,837	3,883	Raw.
16	10	40	3	5,953	2,029	1,103	4,992	5,797	Common.
16	12	45	4	7,938		661	7,481	7,525	Fibrous.
17	15	10	5	10,033	551	1,058	10,553	9,585	Granular.
Totals.	3 days, 8 hrs.		14	27,893 or 12·44 tons.	2,580	3,042	26,863 or 11·99 tons	26,790 or 11·51 tons	

The production was at the rate of 3·14 tons in twelve hours, and for one ton (2240 lbs.) of puddled bar the quantity of materials used was as follows, viz.: 2423 lbs of the mixed irons, 224 lbs. of iron ore, 264 lbs. of hammer-slag, and 2334 lbs. of coal. The trials of the iron produced for the purpose of ascertaining its tensile strength, resulted as follows:

	1st test.	2d test.
Breaking strain per square inch, . . .	55,555 lbs.	55,555 lbs.
Per cent. of elongation before rupture,	19·5 per cent.	20 per cent.

FORGES OF THE JOHN COCKERILL COMPANY.

The great establishment, at Seraing, sent in August, 1874, 22040 lbs. (9·83 tons) of white pig iron, intended for conversion into pud-

dled iron to be used for rail-heads. The trials of this iron were made in the presence of M. Wattieux, engineer of the company, and charges of 2205 lbs. (1000 kil.) each, with an average addition of 110 lbs. of hammer-slag, and there was obtained in 27 hours, 20698 lbs. (9·24 tons) of puddled bar, which was at the rate of 4·1 tons in twelve hours. The consumption of coal, which was of the same quality as that used in previous trials, was at the rate of 1640 lbs. per ton of iron produced.

Works of MM. Michel Helson & Co., at Haumont.

These works sent in September, 1875, 22040 lbs. (9·83 tons) of white pig iron, which was treated in ten charges, with the addition of 132 lbs. of hammer-slag to each charge, and resulted in the production of 20663 lbs. (9·22 tons of ordinary rough puddle bar in 27 hours, which corresponds to a production of 4·09 tons in one day of twelve hours. We will here remark, that it was not necessary to repair the movable bottom of the furnace during the treatment of these ten charges, and consequently it was not necessary to use any iron ore. The coal consumed was at the rate of 1724 lbs. per ton of iron obtained.

Works of MM. Gouvy Brothers, at Dieulourd.

M. Girard, engineer and superintendent of these works, sent to St. Chamond pig irons of various qualities, which were mixed in certain proportions with a view to the production of puddled steel. These mixtures were composed as follows:

Kind of Pig Iron.	Mixture A.	Mixture B.	Mixture C.
Gray, No. 1, . . .	220 lbs.		
" " 2, . . .	430 "	301 lbs.	141 lbs.
" " 5, . . .	421 "	743 "	963 "
English, ...	119 "	119 "	139 "
Spiegel, ...	181 "	181 "	101 "
Totals, . . .	1344	1344	1344

RESULTS OF TRIALS OF THE ABOVE MIXTURES IN THE PERNOT FURNACE.

September 1874.	Days' Work of Furnace.		Number of Charges.	Quality of Pig Iron.	Quantity of			Consumption.		Product of Puddled Steel.
					Pig Iron.	Iron Ore.	Roll Scale	Hammer Slag	Coal.	
	Hrs.	Min.			Lbs.	Lbs.	Lbs.		Lbs.	Lbs.
9	2	30	1	No. 1.	1,345	"	"	St. Chamond	1,343	1,296
10			2	"	1,345	"	"	Gouvy.		1,226
10			3	No. 2.	1.347	"	"	"		1,283
10	13	20	4	"	1,345	"	"	"	7,097	1,213
10			5	½ No.1, ½ No.2	1,345	"	"	"		1,360
10			6	Mixture A.	1,347	"	"	"		1,310
11			7	"	1,347	"	"	"		1,296
11			8	"	1,345	"	"	"		1,274
11	10	20	9	"	1,347	"	"	"	5,907	1,341
11			10	"	1,347	"	"	"		1,349
11	2	10	Repairing the bottom.			1,543	441		959	
12			11	Mixture A.	1,347	"	"	"		1,257
12			12	" B.	1,347	"	"	"		1,288
12	9	10	13	" "	1,345	"	"	"	5,907	1,259
12			14	" C.	1,367	"	"	"		1,239
Total	37 hrs.	30 min.			18,846 or 8·41 tons.	1,543	441		21,213 or 9·47 tons.	17,970 or 8·04 tons.

For the first charge, the hammer-slag of St. Chamond was used, but for the thirteen following charges the slag from the refining fires of MM. Gouvy was employed. The mean production was at the rate of 2·57 tons in twelve hours. To produce one ton (2240 lbs.) of puddled steel, required 2344 lbs. of pig iron and a consumption of 2638 lbs. of coal.

CONCLUSIONS.

From all the foregoing facts we should conclude that the problem of mechanical puddling had been solved in a most satisfactory manner by the system invented by M. Pernot, in fact, with this furnace, the best quality of iron can be produced with more regularity, less loss, and in much greater quantity, than is possible in the old method,

and there is also an important economy in labor, as well as in the consumption of coal and scrap.

In short, we may now be assured that the Pernot process is in every way a practical success. Further experimental trials are unnecessary, for as a method of manufacture fully perfected, we can obtain easily and surely the different products which are produced in a puddling furnace, whether fibrous iron, common iron, or puddled steel.

We mention, finally, a consideration which will not fail to be of interest, it is the good feeling and alacrity with which the workmen have adapted themselves to the experiments, they have understood the consequences from the first, that they would naturally profit from their point of view by the ease and relief in the laborious work of puddling afforded by the new apparatus.

Pernot Furnace.—Applied to the Manufacture of Steel.

The remarkable results of the new method of puddling which we have examined, have induced the inventor, encouraged moreover by MM. Petin & Gaudet, to adapt his furnace to the manufacture of cast steel by the use of gaseous fuel produced and employed by means of the generators and re-generators of M. Siemens, the application of which to the melting of steel in furnaces with fixed bottoms was the idea of M. Martin, and has been effected in a furnace designed by M. Siemens.

The Pernot process, by its special peculiarity of the rotation of the inclined movable bottom, gives great heat and rapid decarbonization, and thus so far modifies the conditions under which the steel is melted that they have no great similarity to those of the old methods.

The gas generators are of the same dimensions as those employed in the Siemens-Martin furnace, but they produce in the same time, three or four times more steel when they are applied to the Pernot system, which not only reduces the expense of fuel, but, what is more important, realizes a great economy in labor, moving power, first cost of erecting plant, and in general expenses. "These results alone, (we quote from the paper read before the Society of Civil Engineers), would ensure the success of such a process, but, the capabilities of the mode of working have much more influence, operations impossible in the old furnaces, being accomplished without difficulty

in this." "By means of this furnace, we can operate upon gray pig iron, without the addition of any scrap iron or scrap steel, and transform it directly into melted wrought iron, which is recarburized by the addition of spiegel, as in the Bessemer process, and is then cast into perfectly malleable steel, which will make excellent rails; the similarity of the chemical reactions to those of the Bessemer process is very great. We also succeed perfectly in casting the steel for rails, without the further addition of pig iron, and the entire operation requires from seven to eight hours for a charge of from nine to eleven thousand pounds."

We will now briefly describe the construction of the furnace for melting with gas which is erected and in use in the new shops at St. Chamond, and will afterwards speak of the advantages which it presents.

Description of a Furnace for Steel.—See Plate.

Fig. 1 shows a side elevation of the furnace and its movable bottom, as seen from the rear.

Fig. 2 is a longitudinal vertical section of the apparatus along the lines 1–2–3–4 of the plan as seen in Fig. 3.

Fig. 3 represents in one part a horizontal at the height of the line 5–6, (Fig. 2), above the movable bottom, and in the other part, a similar section on the line 7–8, (Fig. 2), above the two chambers of the regenerators.

Fig. 4 is a transverse vertical section passing through the axis on line 9–10, (Fig. 2.)

These figures are drawn to a scale, and show the dimensions of a furnace for the production of four or five tons of steel at one time. They show that the apparatus is arranged in a manner similar to that of the puddling furnace we have before described, it has the same "pot" or turning bottom actuated by a small steam engine, but it is heated by the Siemens' method. It is not necessary to give a particular description of this method here, as its successful application and the details of its construction are well known to our readers. The inspection of the Figs. 2, 3 and 4 allows us to examine that which is beneath the furnace proper, and shows the existence of four chambers, R^1, R^2, R^3, R^4, filled with fire-brick, separated from one another so as to permit the

entrance and free passage of the air or the gas which constitutes the gaseous fuel.

This last arrives from the generators by the pipes T in the two cast iron boxes T′, each containing a closing valve, t, and a reversing valve, t', which is worked by means of the hand lever, L′, and directs alternately and methodically the gas into the regenerators R^3 and R^4 on the one side, and into those marked R^1, R^2 on the other side. We notice, also, that each of the valve boxes is placed above the opening, O^1, which communicates with the chimney flue, O^2, and has at its base a chest, T^2, (Fig. 3), which covers the openings o^1 and o^2, by which it communicates with the flues, P^3 and P^4. These arrangements are designed to direct, for a certain time, the gas and air destined to enter into combustion in the furnace, whilst the two other regenerators are heated by the products of this combustion passing in an inverse direction; when these last two have been sufficiently heated, we reverse the valves t^1 for changing the directions of the currents of gas and air, which produces a similar effect as before, but in an inverse direction.

The mode of heating the furnace proper differs little from that which has been described; under the roof, C, in the piers, A, are placed the flues, A^1 and A^2, for the ingress and egress of the gas and air by the large openings which permit a free passage to the inclined "pot," H, on its carriage, R, which is able to enter and leave the furnace freely and easily on the rails, S.

The "pot" is made to rotate by means of a steam engine, O, which, by the wheel, M, and the pinions, N and L, actuates the bevel gear, K, fixed under the bottom of the envelope which is pierced with holes for the purpose of cooling when necessary in the same way as in the puddling furnace. The furnace is provided with a working opening, c, closed by the hanging door, d, and the "pot" is provided with a tap-hole, h, which when open affords a passage for the cast steel to the ladle, V, by means of the gutter, U.

The ladle is placed as in the Bessemer process (which we have described in vols. xiv and xv) in the interior of a large pit, F^1, 15 or 18 feet in diameter; at the same distance from circumference of the pit, as the tap-hole, v, are arranged in a circle, close to one another, the ingot moulds, which are put in place and removed, by the aid of an over-head crane with a radial arm having its point of suspension directly over the centre of the pit, and, consequently above the

buried pivot which supports the arm, V^1, of the ladle, V. By this means the successive removals of all the moulds is accomplished with great promptness and facility, and without inconvenience to the other operations.

Management of the Apparatus.

We will state at the outset, that the bottom is made of siliceous sand, reheated and annealed. As soon as the furnace is sufficiently hot, we immediately charge the quantity of pig iron necessary to form a proper bath, say, for example, from one to one and one-half tons. To distribute this quantity uniformly over the bottom is an operation simple and easy, by causing the "pot" to rotate, and successively present all parts of the charge before the working doors. After the distribution, the iron is exposed to a high temperature and soon becomes liquid; we introduce then, in the same way, the remainder of the charge, consisting of either scrap iron, crop ends of steel, and old rails, which may be used if they are not more than three or three and one-half feet long; we can effect this charging cold; and at one time, or, what is better, in parts, the pieces of metal being previously heated to a red heat in an ordinary furnace; by this means we do not cool the bath. In consequence of the mobility of the bottom, the heat penetrates regularly through the whole of the mass and the pieces of metal as they are successively immersed in the bath augment its volume.

It is worthy of note that this immersion being complete, the pig iron, wrought scrap, and the rails, do not become burned, which is inevitable in a furnace with a fixed bottom, if we charge too much at a time, that is to say, more than the bath will properly cover. Charging the whole of the materials at once has the advantage of diminishing the number of men employed at the furnace, for, we have not so much detail to the labor, and they can be employed at other work as soon as the charge is completed.

When this is accomplished the working door is closed and the heat increased, the "pot" being turned at the rate of two or three revolutions per minute. The charge is melted in from two to three hours, and soon after we commence to take what is called the "tests" in order to ascertain the degree of decarburization. It appears necessary to explain briefly the method of making the "test," which is accomplished without retarding the operation, enabling the workmen

Pernot Furnace for melting 4 to 5 Tons of Steel.

Fig. 4.

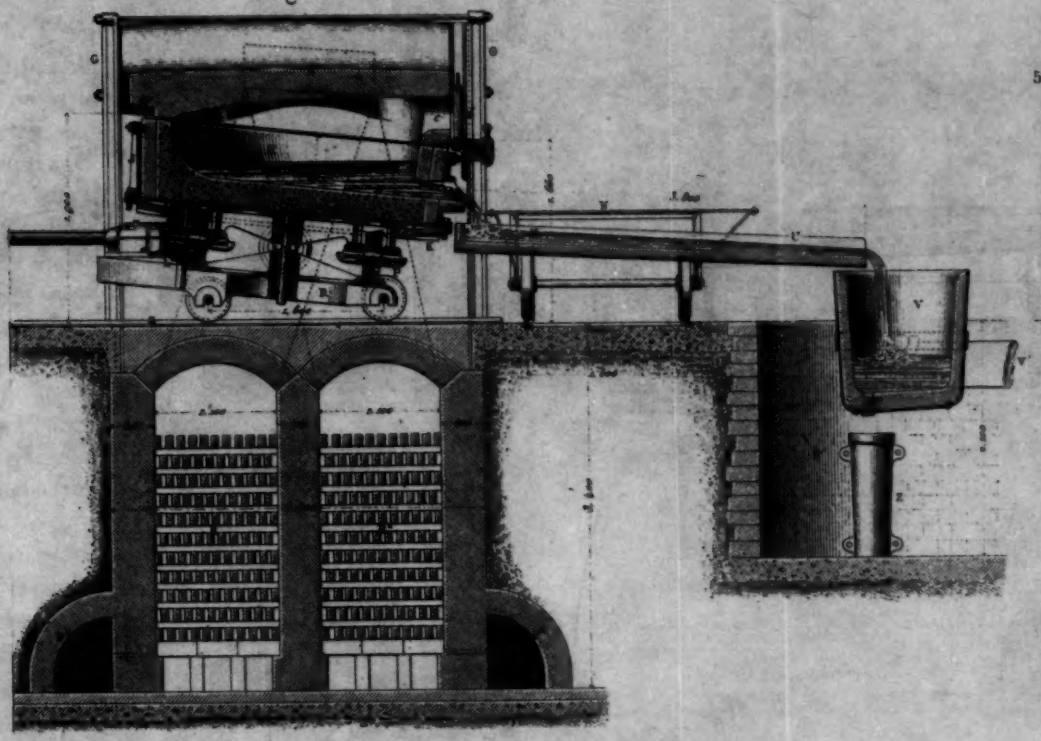
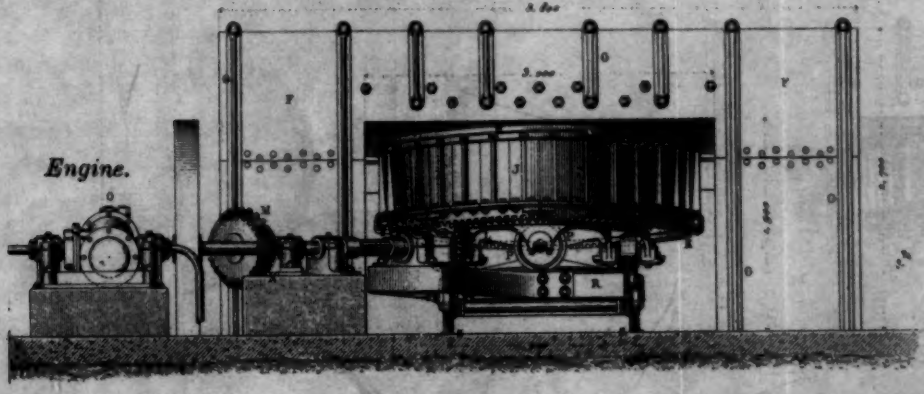


Fig. 1.



...ons of Steel per charge.

Fig. 2.

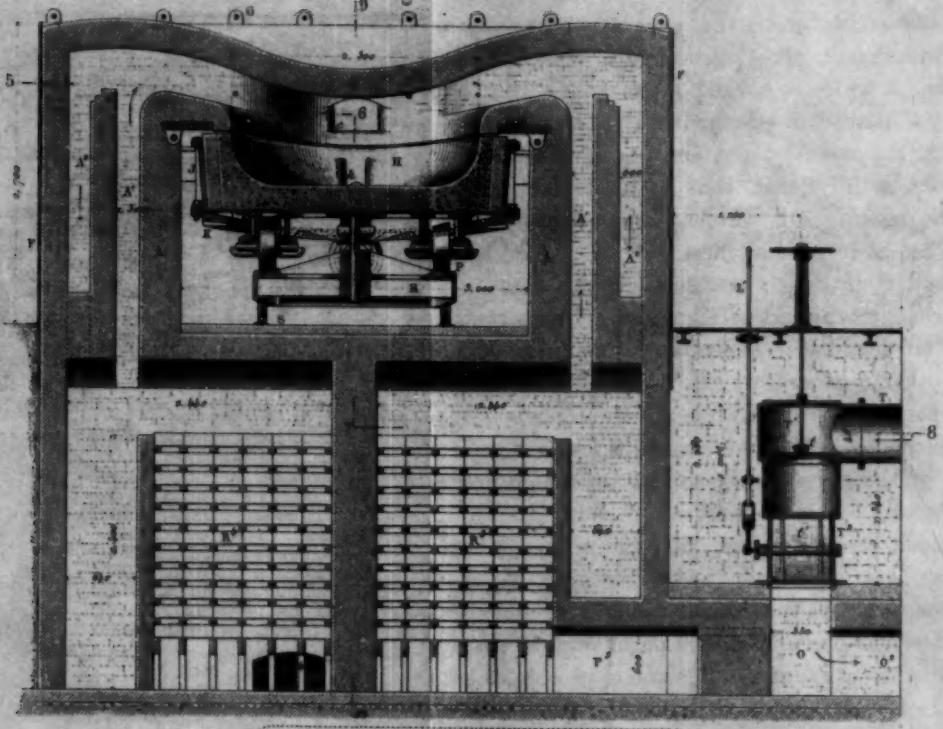
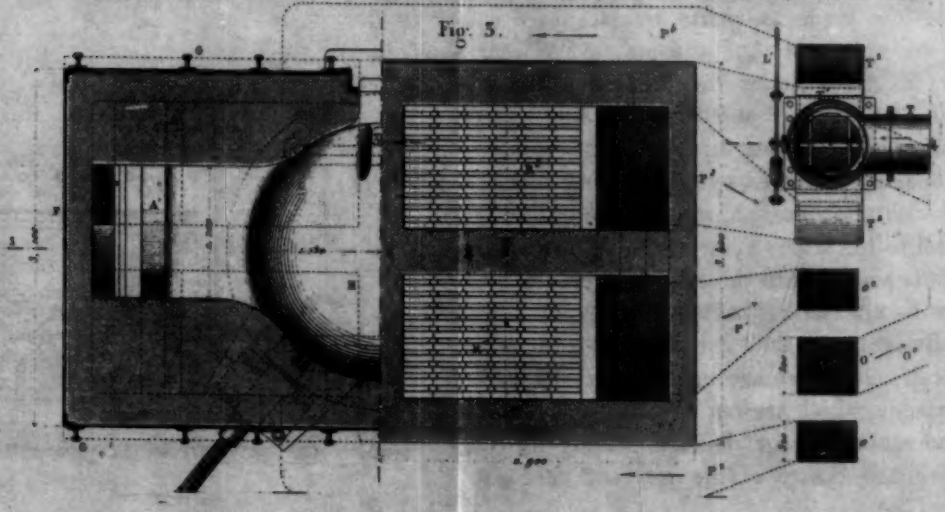


Fig. 3.



in charge of the furnace to proceed with entire confidence. Having observed this operation with great care and attention, we may be allowed to speak of it with confidence.

There is generally two tests, the first is taken as soon as the whole of the mass is completely melted and decarbonized. We then, by means of a long handled ladle or spoon, take a small quantity of the melted material, two pounds for example, which, after it solidifies, we take to a steam-hammer and form it into a sort of flat and round cake, three or four inches in diameter, and not over three-eighths of an inch thick. We cool this disc by dipping it in a vessel of water, and we then place it on an angular groove cut in a steel block, and by striking it in the middle it is made to bend and finally to break into two parts. Under the action of the hammer there is formed on the circumference of the disc a great number of cracks, which are certain indications to the workman of the character of the metal.

According as the "test" bends with more or less ease before it is broken, it is judged that the metal requires more or less wrought iron, and if it is fractured easily, it is evident that the metal is brittle rather than tough. This "test" allows us to correct the charge and to determine the quantity of "spiegel," that is to say, the manganiferous pig iron which it is necessary to add to the fused mass in order to give it the degree of carburization suited to the nature of the steel we desire to obtain. Thus in practice, when the mass has too much wrought iron, we use, to correct it, as much as eight or nine per cent. of "spiegel," or 1000 lbs. for every 9000 lbs. of the melted mass contained in the "pot." In the contrary case we add but four or five per cent. of "spiegel."

The pigs of "spiegel" after having been weighed are heated in a neighboring furnace (as was the wrought iron) and carried on a car, X, (Fig. 4), to the melting furnace. The men stand on the car with forks, and throw into the furnace all the "spiegel" as rapidly as possible, which is immediately received and drowned in the fused bath, the heat of which is maintained and its turning continued. After ten or twelve minutes the whole of the "spiegel" is completely melted. We now make the second "test" by taking a small quantity of metal and proceeding as before, submit it to a steam-hammer and form it into a disc, which does not present the same aspect as the first, but instead of its edges being cracked, they are, on the contrary, very smooth, without cracks, and after cooling, it is broken at the angular groove

by one blow on the "sett," the fracture showing a homogeneous grain very fine and close.

During this last "test," which requires two or three minutes, the furnace continues its movement, which has not been interrupted during the heat, except when the workmen examined and prepared the tap-hole. When ordered, the men remove the stopper from the tap-hole in the side of the "pot," and the liquid metal flows through the gutter, U, (which is lined with fire-clay) into the large ladle, V, which has been previously heated. This ladle is of sufficient capacity to contain from 9 to 11,000 lbs. of melted metal.

After the tapping, nothing remains in the bottom and as we never find in the Pernot furnace, as in the furnaces with fixed bottoms, pieces of rails which are not melted, or lumps of metal adhering to the sides, the delay to the process after this operation is very short, and after beating the bottom a little we re-charge immediately. The duration of an operation, including the charging and repairs, is but four or five hours at most, for a charge of nine thousand pounds. The daily product at the works of St. Chamond is twenty tons of steel in twenty-four hours, and we think this will be exceeded when the working force is properly trained. Besides we must observe that this is not the limit to the dimensions of the apparatus or to the production, for at the time of our visit we saw a new furnace built on the same idea which is capable of receiving charges of ten tons.

From the first day this furnace was fired it worked satisfactorily, and accomplished with certainty the results which were hoped for, four tappings being made in twenty-four hours, which corresponds to a product of 40 tons per day, or $40 \times 300 = 12000$ tons per year. For a furnace of this capacity, it is sufficient to increase the diameter of the "pot" two feet, and it is worthy of remark that the heating apparatus is exactly the same as in the furnace represented n the Plate, and offers the same advantage in saving fuel.

This is explained by the fact that the surface exposed to the flame is considerable in proportion to the small thickness of the layer of metal which is continually presented to its action. If we have a circular "pot" ten feet in diameter, the area of its section is 78·5 square feet. But ten tons of pig iron and scrap at a mean weight of 437 lbs. per cubic foot forms a volume of 51·5 cubic feet, and consequently occupies a depth of about eight inches in the "pot."

For the five ton furnace, the diameter of the "pot" is 8 feet 3 inches, and the surface in contact with the gas is about 53·5 square feet, and the volume of the metal is about 25·6 cubic feet, hence its thickness is about 5½ inches; it is certain that the dimensions given of the gas generators are more than sufficient; as we have said, they are similar to those adopted by M. Martin for his furnace with a fixed bottom, and they are capable of furnishing the heat necessary for an apparatus very much larger.

Advantages of the System.

As we have demonstrated in regard to the puddling, so the advantages of the application of the new furnace of M. Pernot to the manufacture of steel are very marked and consist of:

1st. A considerable increase of the production, since an apparatus of 8 feet 3 inches in diameter, receiving charges of four or five tons, will easily turn out 20 tons in 24 hours, while the Siemens–Martin furnace will not produce more than 10 tons in that time.

2d. A reduction of some importance in the amount of the labor, fuel, general expenses, and cost of repairs.

3d. A considerable economy in the net cost, since after the first trials were made, during a period of three weeks, with materials costing $31.32 per ton, the mean net cost of product according to the books of MM. Petin & Gaudet, appears to be $43.02 per ton, whilst with the same materials used in the Siemens–Martin furnace, the net cost becomes $50.90.

4th. The repairs of the roof and other parts of the furnace are easily and rapidly accomplished. Owing to the mobility of the car, we can remove the "pot" from the furnace, and the enormous opening which it leaves allows us freely to enter and make repairs after the expiration of a few hours, which are necessary for cooling. In ten hours the workmen make an entire roof, and if greater repairs are necessary, one day will probably be sufficient for making them, and re-heating the furnace. This is very advantageous as the routine of the works is but slightly interrupted.

5th. The first cost considered relative to the production is small. In fact, according to the paper presented by M. J. Petin to the Society of Civil Engineers, the cost of a Pernot furnace, for converting at one operation four or five tons of metal into steel, is placed at $7688·00, but three furnaces, capable of melting together 60 or

eighty tons in 24 hours, are sufficient to replace two Bessemer converters requiring an outlay of more than $60,000.

6th. The operation can always be modified in various ways up to the time of tapping, which is a great advantage, and one not possessed by the Bessemer process.

7th. The steel is perfectly homogeneous, owing to the mixing of the metal produced by the rotation of the "pot" this saves the stirring by hand and consequently the use of tools.

8th. Finally, the Pernot process is applied with the same success to a small as to a large production without requiring in any case the erection and maintenance of the gigantic machinery which characterizes the Bessemer process.

CARILLON MACHINE.*

Most of our readers have heard church bells play tunes. At one period such an arrangement was very common, and on the Continent of Europe the system was brought to considerable perfection; but in England the results obtained were not satisfactory, and it is only within a recent period that the employment of machinery for the production of airs from church bells has become popular. The progress of the movement is due, beyond question, to Messrs. Gillett and Bland, of Croydon. These gentlemen manufacture clocks on a very large scale, and they have devoted much attention to the improvement of carillon machinery, and have achieved great success.

As the method of producing tunes from church bells is but little understood, it will be well to preface our description of the machine we illustrate by a few words of explanation.

Church bells are caused to sound in two ways—either, that is to say, by swinging them, and so causing the clappers to strike them; or by the aid of hammers of various weights according to the size of the bell, caused to rise and suffered to fall on the bell. Peals are rung by hand, the bells being swung; clocks always strike the bell with a

* From the *Engineer*, London, Aug. 13, 1875.

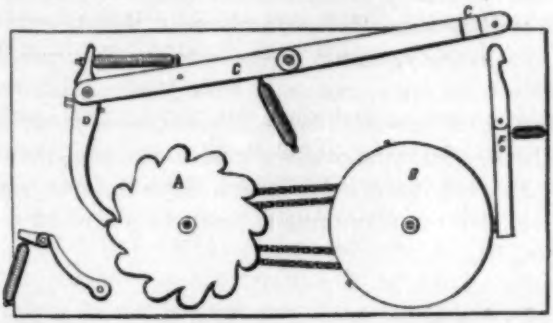
hammer, the bell being at rest. The hammer is raised by a wire, which pulls down the hammer tail, the wire being worked by a lever, the end of which is caught by a cam on a revolving barrel in the clock below. It is obvious that if a number of bells are all fitted with hammers, and the number of cams is sufficiently great, and the cams are properly arranged, that a tune can be played by a mere multiplication of the device by which a clock is made to strike the hours on a single bell.

The carillon machine embodies this arrangement, only instead of cams, a number of short pins are set in a revolving barrel, and these pins catch the toes of levers connected by wires with the hammer tails in the bell chamber above. The pins are set or "pricked in precisely in the same way as the little points in the barrel of a musical box. If our readers will bear the musical box in mind, and fancy that the whole is enormously enlarged, and that the toes of the levers take the place of the springs, the arrangement will be quite clear. Such is the old-fashioned, or, as we may term it, "positive," carillon machine; and its defects are very serious.

In the first place, after the hammer has been suffered to fall, it can only be lifted by the rotation of the barrel, and as the time of dropping the hammer depends entirely on the rotation of the barrel, it is obvious that the barrel can only revolve at a slow speed, and, consequently, much time is lost in lifting the hammer. The result is that a rapid musical passage cannot possibly be performed. The weight of a hammer for a large bell is sometimes as much as 3 cwt., while that for a small bell may not be one-fourth of this; but the musical barrel always has the same propelling force, and the result is that when the small bells, or high notes, come to be played in any tune, the barrel meets with less resistance, and revolves faster than when it has to deal with the deep notes and large bells. It follows that the air is played out of time. Lastly, the barrel must be of great size, weight and strength to do the work.

All these difficulties are overcome by the invention of Messrs. Gillett and Bland illustrated in the diagram—which explains a principle, and not details. This principle we may call "negative." The hammers are always kept raised, and are only allowed to drop by the agency of the musical barrel. The instant they fall they are lifted again, and so long as the lifting is accomplished quickly enough, the time of lifting has nothing to do with the production of the air. That is de-

termined solely by the musical barrel, which, being relieved of the work of lifting, has little or no strain on it, can be made small and light, and will always revolve at the same rate, and so insure that the tune shall be played in perfect time. It also follows that the most rapid passages can be played with the greatest ease and precision.



The diagram is supposed to show the gear for working one hammer. It must be multiplied in proportion to the number of hammers, but the parts are all repetitions of each other. It will be understood that the diagram does not show details, but simply illustrates a principle.

The musical barrel B is set with pins in the usual way. A is a cam wheel of very peculiar construction, operating a lever C by what is to all intents and purposes, a new mechanical motion, the peculiarity of which is that, however fast the cam wheel revolves, the tripping of the lever is avoided. In all cases the outer end must be lifted to its full height before the swinging piece D quits the cam. The little spring roller E directs the tail D of the lever into the cam space, and when there it is prevented from coming out again by a very simple and elegant little device, which Messrs. Gillet and Bland do not at present desire to be made public, by which certainty of action is secured. At the other end of the lever C is a trip lever F. This lever is pulled toward C by a spring, and whenever C is thrown up by the cam wheel, F seizes it and holds it up; but the wire to the bell hammer in the tower above is secured to the eye G, so that when D is lifted, the eye G being pulled down, the hammer is lifted. The pins in the musical barrel B come against a step in F, and as they pass by they push F outwards and release C, which immediately drops, and with it the hammer, so that the instant a pin passes the step F a note is sounded. But the moment D drops it engages with A, which last

revolves at a very high speed, and D is incontinently flung up again, and the hammer raised, and raised it remains until the next pin on B passes the step on F, and again a note is struck. It will be seen, therefore, that, if we may use the phrase, B has nothing to do but let off traps set continually by A, and so long as A sets the traps fast enough, B will let them off in correct time. But A revolves so fast and acts so powerfully, that it makes nothing of even a 3 cwt. hammer, much less the little ones; and thus Messrs. Gillett and Bland obtain a facility of execution heretofore unknown in carillon machinery. A Carillon Machine can be actuated not only by means of the barrel B, but can have a key-board, same as for a piano-forte, so that any musician can play tunes as easily as played on a piano-forte or an organ.

THE PROPOSED INLAND SEA IN ALGERIA.

Some time since a project was conceived by Captain Roudaire, of the French Navy, to fill the immense depressions, which are known under the name of "chotts," with water from the Mediterranean. The subject attracted great attention, and was brought before the Academy of Sciences by M. de Lesseps.

After some discussion, during which many objections were raised against the project, an expedition, headed by Captain Roudaire, was appointed to take the levels of the region of the chotts, in order to determine the extent of the area which was capable of being submerged. The expedition included two captains and a lieutenant of the Etat Major, an infantry captain, a surgeon-major, M. Duvegrier, deputed by the Geographical Society of France, and a young mining engineer. The expedition has completed its work, and M. de Lesseps has reported upon it to the Academy.

The operations continued without a breach for more than four months, the entire tour of the chotts having been made, and El Oued and Négrine connected by a transverse profile, the whole making a distance of 650 kilometers. The result is that the depression capable of being flooded in Algeria forms an area of 6,000 square kilometers, included within 34·38° and 33·51° north latitude, and 4·51° and 3·40° east longitude. In the central portion the depression varies from 20 to 27 meters below the sea level.

None of the fine oases of the Souf would be immerged by the inletting of the sea, the lowest of them, Debila, being 58 meters above the sea. In the Oued-Rhir, the two unimportant oases of Necira and Deudonga would alone be submerged.

It was suggested that the presence of the salt-water would affect the wells which fertilize the oases, but M. Roudaire affirms that he found that all the wells, even those nearest to the basin to be inundated, were fed by a source of water higher than the sea level.

The expedition not being able to cross the Tusinian frontier, were only able to examine the western end of the chott Rharsa, but they ascertained that it was also below the level of the Mediterranean, and had an incline of about 2·20 meters per kilometer towards the Gulf of Gabés.

The basins of the chott Rharsa and chott Melrir, although connected by the chott El-Asloudj, are not now in direct communication, for the last-named chott has an altitude of 3·20 meters in its central part, and is, moreover, bounded on the east and west by a chain of dunes. These dunes of Bou-Douil and of Zeninim may be easily cut through at passes of which the greatest altitude does not exceed 6 to 7 meters; the distance to excavate would be 20 kilometers. It is suggested that the chott Rharsa might first be inundated, and then a communication being made with chott Melrir by a cutting, the sea would soon open it to the necessary size and depth.

A great question remains yet to be answered, namely, the amount of difficulty there would be in cutting through the Isthmus of Gabés. Opinion differs upon this point. M. Fuchs, a mining engineer, who has explored the region, gives the Isthmus a relief of 40 to 50 meters, but his levels were only taken with an aneroid barometer, and at points, so that the question is still open.

At the present moment an Italian Commission is taking levels in that part, and when the results of their labors are known, the cost of piercing this isthmus, and the possibility in an economical point of view of carrying out his stupendous project of an inland sea, will be determined.

The existence of the vast depression, which some persons dispute, is considered to be placed beyond all question by the observations of Captain Roudaire and his associates.—*Journal of the Society of Arts.*

Chemistry, Physics, Technology, etc.

PRELIMINARY NOTICE OF FURTHER RESEARCHES ON THE PHYSICAL PROPERTIES OF MATTER IN THE LIQUID AND GASEOUS STATES UNDER VARIED CONDITIONS OF PRESSURE AND TEMPERATURE.*

By Dr. Andrews, F. R. S., Vice-President of Queen's College, Belfast.

The investigation to which this note refers has occupied me, with little intermission, since my former communication in 1869 to the Society, "On the Continuity of the Liquid and Gaseous States of Matter." It was undertaken chiefly to ascertain the modifications which the three great laws discovered respectively by Boyle, Gay-Lussac, and Dalton undergo when matter in the gaseous state is placed under physical conditions differing greatly from any hitherto within the reach of observation. It embraces a large number of experiments of precision, performed at different temperatures and at pressures ranging from 12 to nearly 300 atmospheres. The apparatus employed is, in all its essential parts, similar to that described in the paper referred to; and so perfectly did it act, that the readings of the cathetometer, at the highest pressures and temperatures employed, were made with the same ease and accuracy as if the object of the experiment had been merely to determine the tension of aqueous vapor in a barometer tube. In using it the chief improvement I made is in the method of ascertaining the original volumes of the gases before compression, which can now be known with much less labor and greater accuracy than by the method I formerly described. The lower ends of the glass tubes containing the gases dip into small mercurial reservoirs formed of thin glass tubes, which rest on ledges within the apparatus. The arrangement has prevented many failures in screwing up the apparatus, and has given more precision to the measurements. A great improvement has also been made in the

* A paper read before the Royal Society.

method of preparing the leather washers used in the packing for the fine screws, by means of which the pressure is obtained. It consists in saturating the leather with grease by heating it *in vacuo* under melted lard. In this way, the air enclosed within the pores of the leather is removed without the use of water, and a packing is obtained so perfect that it appears, as far as my experience goes, never to fail, provided it is used in a vessel filled with water. It is remarkable, however, that the same packing, when an apparatus specially constructed for the purpose of forged iron was filled with mercury, always yielded, even at a pressure of 40 atmospheres, in the course of a few days.

It is with regret that I am still obliged to give the pressures in atmospheres, as indicated by an air or hydrogen manometer, without attempting for the present to apply the corrections required to reduce them to true pressures. The only satisfactory method of obtaining these corrections would be to compare the indications of the manometer with those of a column of mercury of the requisite length; and this method, as is known, was employed by Arago and Dulong, and afterwards in his classical researches by Regnault, for pressures reaching nearly to 30 atmospheres. For this moderate pressure, a column of mercury about 23 meters or 75 feet in length, had to be employed. For pressures corresponding to 500 atmospheres, at which I have no difficulty in working with my apparatus, a mercurial column of the enormous height of 380 meters, or 1250 feet, would be required. Although the mechanical difficulties in the construction of a long tube for this purpose are, perhaps, not insuperable, it could only be mounted in front of some rare mountain escarpment, where it would be practically impossible to conduct a long series of delicate experiments. About three years ago, I had the honor of submitting to the Council of the Society a proposal for constructing an apparatus which would have enabled any pressure to be measured by the successive additions of the pressure of a column of mercury at a fixed length; and working drawings of the apparatus were prepared by Mr. J. Cumine, whose services I am glad to have again this opportunity of acknowledging. An unexpected difficulty, however, arose in consequence of the packing of the screws (as I have already stated) not holding when the leather was in contact with mercury instead of water, and the apparatus was not constructed. For two years the problem appeared, if not theoretically, to be prac-

tically impossible of solution; but I am glad now to be able to announce to the Society that another method, simpler in principle, and free from the objections to which I have referred, has lately suggested itself to me, by means of which it will, I fully expect, be possible to determine the rate of compressibility of hydrogen or other gas by direct reference to the weight of a liquid column, or rather of a number of liquid columns, up to pressure of 500 or even 1000 atmospheres. For the present, it must be understood that in stating the following results, the pressures in atmospheres are deduced from the apparent compressibility in some cases of air, in others of hydrogen gas contained in capillary glass tubes.

In this notice I will only refer to the results of experiments upon carbonic acid gas, when alone or when mixed with nitrogen. It is with carbonic acid, indeed, that I have hitherto chiefly worked, as it is singularly well adapted for experiment; and the properties it exhibits will doubtless, in their main features, be found to represent those of other gaseous bodies at corresponding temperatures below and above their critical points.

Liquefaction of Carbonic Acid Gas.—The following results have been obtained from a number of very careful experiments, and give, it is believed, the pressures, as measured by an air-manometer, at which carbonic acid liquefies for the temperatures stated:

Temperatures in Centigrade Degrees.	Pressure in Atmospheres.
0·00	35·04
5·45	40·44
11·45	47·04
16·92	53·77
22·22	61·13
25·39	65·78
28·30	70·39

I have been gratified to find that the two results (for 13·09° and 21·46°) recorded in my former paper are in close agreement with these later experiments. On the other hand, the pressures I have found are lower than those given by Regnault as the results of his elaborate investigation (*Mémoires de l'Académie des Sciences*, vol. xxvi, p. 618). The method employed by that distinguished physicist was, not, however, fitted to give accurately the pressures at which carbonic acid gas liquefies. It gave, indeed, the pressures exercised

by the liquid when contained in large quantity in a Thilorier's reservoir; but these pressures are always considerably in excess of the true pressures, in consequence of the unavoidable presence of a small quantity of compressed air, although the greatest precautions may have been taken in filling the apparatus. Even $\frac{1}{500}$th part of air will exercise a serious disturbing influence when the reservoir contains a notable quantity of liquid.

Law of Boyle.—The large deviations in the case of carbonic acid at high pressures from this law appeared distinctly from several of the results given in my former paper. I have now finished a long series of experiments on its compressibility at the respective temperatures of 6·7°, 63·7°, and 100° C. The two latter temperatures were obtained by passing the vapors of pyroxylic spirit (methyl-alcohol) and of water into the rectangular case with plate-glass sides, in which the tube containing the carbonic acid is placed. The temperature of the vapor of the pyroxylic spirit was observed by an accurate thermometer, whose indications were corrected for the unequal expansion of the mercury: while that of the vapor of water was deduced from the pressure as given by the height of the barometer and a water-gauge attached to the apparatus. At the lower temperature (6·7°), the range of pressure which could be applied was limited by the occurrence of liquefaction; but at the higher temperatures, which were considerably above the critical point of carbonic acid, there was no limit of this kind, and the pressures were carried as far as 223 atmospheres. I have only given a few of the results; but they will be sufficient to show the general effects of the pressure. In the following tables p designates the pressure in atmospheres as given by the air manometer, t' the temperature of the carbonic acid, e the ratio of the volume of the carbonic acid under one atmosphere and at the temperature t' to its volume under the pressure p' and at the same temperature, and θ the volume to which one volume of carbonic acid gas measured at 0° and 760 millimetres is reduced at the pressure p and temperature t'.:

Carbonic Acid at 6·7°.

p.	t'	e.	θ.
Atmospheres.	Degrees.		
13·22	6·90	$\frac{1}{14·36}$	0·07143

20·10	6·79	$\frac{1}{23·01}$	0·44456
24·81	6·73	$\frac{1}{29·60}$	0.03462
31·06	6·62	$\frac{1}{39·57}$	0·02589
40·11	6·59	$\frac{1}{58·40}$	0·01754

Carbonic Acid at 63·7°.

p. Atmospheres.	*t'* Degrees.	*e.*	*θ.*
16·96	63·97	$\frac{1}{17·85}$	0·06931
54·33	63·57	$\frac{1}{66·06}$	0·01871
106·88	63·75	$\frac{1}{185·90}$	0·00665
145·54	63·70	$\frac{1}{327·30}$	0·00378
222·92	63·82	$\frac{1}{446·90}$	0·00277

Carbonic Acid at 100°.

p. Atmospheres.	*t'* Degrees.	*e.*	*θ.*
16·80	100·38	$\frac{1}{17·33}$	0·07914
53·81	100·33	$\frac{1}{60·22}$	0·02278
105·69	100·37	$\frac{1}{137·10}$	0·01001
145·44	99·46	$\frac{1}{218·90}$	0.00625

223·57	99·44	$\frac{1}{380·90}$	0·00359

These results fully confirm the conclusions which I formerly deduced from the behavior of carbonic acid at 48°, viz., that while the curve representing its volume under different pressures approximates more nearly to that of a perfect gas as the temperature is higher, the contraction is nevertheless greater than it would be if the law of Boyle held good, at least for any temperature at which experiments have yet been made. From the foregoing experiments it appears that at 63.7° carbonic acid gas, under a pressure of 223 atmospheres, is reduced to $\frac{1}{477}$th of its volume under one atmosphere, or less than one-half the volume it ought to occupy if it were a perfect gas, and contracted in conformity with Boyle's law. Even at 100° the contraction under the same pressure amounts to $\frac{1}{381}$st part of the whole. From these observations we may infer, by analogy, that the critical points of the greater number of the gases not hitherto liquefied, are probably far below the lowest temperature hitherto attained, and that they are not likely to be seen, either as liquids or solids, till much lower temperatures even than those produced by liquid nitrous oxide are reached.

Law of Gay-Lussac.—That the law of Gay-Lussac in the case of the so-called permanent gases, or in general terms of cases greatly above their critical points, holds good at least at ordinary pressures, within the limits of experimental error, is highly probable from the experiments of Regnault; but the results I have obtained with carbonic acid will show that this law, like that of Boyle, is true only in certain limiting conditions of gaseous matter, and that it wholly fails in others. It will be shown that not only does the coefficient of expansion change rapidly with the pressure, but that, *the pressure or volume remaining constant, the coefficient changes with the temperature.* The latter result was first obtained from a set of preliminary experiments in which the expansion of carbonic acid under a pressure of 17 atmospheres was observed at 4°, 20°, and 54°; and it has since been fully confirmed by a large number of experiments, made at different pressures and well-defined temperatures. These experiments were conducted by the two methods commonly known as the method of constant pressure and the method of constant volume. The two methods, except in the limiting conditions, do not give the same values

for the coefficient of expansion; but they agree in this respect, that at high pressures the value of that coefficient changes with the temperature. While I have confined this statement to the actual results of experiment, I have no doubt that future observations will discover, in the case, at least, of such gases as carbonic acid, a similar, but smaller, change in the value of the coefficient for heat at low pressures. The numerous experiments I have made on this subject will shortly be communicated in detail to the Society; and for the present I will only give the following results :—

Expansion of Heat of Carbonic Acid Gas under High Pressures.

Pressure.	Vol. CO_2 at 0° and 760 m.m. = 1.	Vol. CO_2 at 6·05° and 22·26 At. = 1.	Temperature.	
Atmospheres.			Degrees.	
22·26	0·03934	1·0000	6·05	(A)
22·26	0·05183	1·3175	63·79	
22·26	0·05909	1·5020	100·10	

Pressure.	Vol. CO_2 at 0° and 760 m.m. = 1.	Vol. CO_2 at 6·62° and 31·06 At. = 1.	Temperature.	
Atmospheres.			Degrees.	
31·06	0·02589	1·0000	6·62	(B)
31·06	0·03600	1·3905	63·83	
31·06	0·04160	1·6068	100·64	

Pressure.	Vol. CO_2 at 0° and 760 m.m. = 1.	Vol. CO_2 at 6·01° and 40·06 At. = 1.	Temperature.	
Atmospheres.			Degrees.	
40·06	0·01744	1·0000	6·01	(C)
40·06	0·02697	1·5464	63·64	
40·06	0·03161	1·8123	100 60	

Taking as unit 1 vol. of carbonic acid at 6·05° and 22·26 atmospheres, we obtain, from series A, the following values for the coefficient of heat for the different ranges of temperature :—

$a = 0{\cdot}005499$ from 6·05° to 63·79°.
$a = 0{\cdot}005081$ from 63·79° to 100·10°.

From series B, with the corresponding unit volume at 6·62° and 31·06 atmospheres, we find:—

$$a = 0{\cdot}006826 \text{ from } 6{\cdot}62° \text{ to } 63{\cdot}83°.$$
$$a = 0{\cdot}005876 \text{ from } 63{\cdot}83° \text{ to } 100{\cdot}64°.$$

And in like manner, from series C, with the unit volume at 6·01° and 40·06 atmospheres:—

$$a = 0{\cdot}009481 \text{ from } 6{\cdot}01° \text{ to } 63{\cdot}64°.$$
$$a = 0{\cdot}007194 \text{ from } 63{\cdot}64° \text{ to } 100{\cdot}60°.$$

The coefficient of carbonic acid under 1 atmosphere referred to a unit volume at 6° is—

$$a = 0{\cdot}003629.$$

From these experiments, it appears that the coefficient of expansion increases rapidly with the pressure. Between the temperatures of 6° and 64° it is once and a half as great under 22 atmospheres, and more than two and a half times as great under 40 atmospheres, as at the pressure of 1 atmosphere. Still more important is the change in the value of the coefficient at different parts of the thermometric scale, the pressure remaining the same. An inspection of the figures will also show that this change of value at different temperature increases with the pressure.

Another interesting question and one of great importance in reference to the laws of molecular action, is the relation between the elastic forces of a gas at different temperatures while the volume remains constant. The experiments which I have made in this part of the inquiry are only preliminary, and were performed, not with pure carbonic acid, but with a mixture of about 11 vols. of carbonic acid and 1 vol. of air. It will be convenient, for the sake of comparison, to calculate, as is usually done, the values of a from these experiments; but it must be remembered that a here represents no longer a coefficient of volume, but a coefficient of elastic force.

Elastic Force of a Mixture of 11 *vols.* CO_2 *and* 1 *vol. Air Heated under a constant volume to different temperatures.*

Vol. CO_2.	Temperature. Degrees.	Elastic Force. Atmospheres.	
366·1	13·70	22·90	(A)
366·2	40·63	25·74	
366·2	99·73	31·65	

256·8	13·70	31·18	(B)
256·8	40·66	35·44	
256·8	99·76	44·29	

From series A we deduce, for a unit at 13·70° and 22·90 atmospheres :—

$a = 0{\cdot}004604$ from 13·70° to 40·63°.
$a = 0{\cdot}004367$ from 40·63° to 99·73°.

And from series B :—

$a = 0{\cdot}005067$ from 13·70° to 40·66°.
$a = 0{\cdot}004804$ from 40·66° to 99·75°.

The coefficient at 13·70° and 1 atmosphere is—

$$a = 0{\cdot}003513.$$

It is clear that the changes in the value of a, calculated from the elastic forces under a constant volume, are in the same direction as those already deduced from the expansion of the gas under a constant pressure. The value of a increases with the pressure, and it is greater at lower than at higher temperatures. But a remarkable relation exists between the coefficients in the present case which does not exist between the coefficients obtained from the expansion of the gas. The values of a, deduced for the same range of temperature from the elastic forces at different pressures, are directly proportional to one another. We have, in short—

$$\frac{0{\cdot}004367}{0{\cdot}004604} = 0{\cdot}9485, \qquad \frac{0{\cdot}04804}{0{\cdot}05067} = 0{\cdot}9481.$$

How far this relation will be found to exist under other conditions of temperature and pressure will appear when experiments now in progress are brought to a conclusion.

Law of Dalton.—This law, as originally enunciated by its author, is, that the particles of one gas possess no repulsive or attractive power with regard to the particles of another. "Oxygen," he states, "azotic gas, hydrogenous gas, carbonic acid gas, aqueous vapor, and probably several other elastic fluids, may exist in company under any pressure and at any temperature without any regard to their specific gravities, and without any pressure upon one another." The experiments which I have made on mixtures of carbonic acid and nitrogen have occupied a larger portion of time than all I have yet referred to.

They have been carried to the great pressure of 283·9 atmospheres, as measured in glass tubes by a hydrogen manometer, at which pressure a mixture of 3 volumes of carbonic acid and 4 volumes of nitrogen was reduced at 7·6°, to $\frac{1}{278}$th of its volume without liquefaction of the carbonic acid. As this note has already extended to an unusual length, I will not now attempt to give an analysis of these experiments, but shall briefly state their general results. The most important of these results is *the lowering of the critical point by admixture with a non-condensable gas.* Thus, in the mixture mentioned above of carbonic acid and nitrogen, no liquid was formed at any pressure until the temperature was reduced below — 20° C. Even the addition of only $\frac{1}{10}$th of its volume of air or nitrogen to carbonic acid gas will lower the critical point several degrees. Finally, these experiments leave no doubt that the law of Dalton entirely fails under high pressures, where one of the gases is at a temperature not greatly above its critical point. The anomalies observed in the tension of the vapor of water when alone and when mixed with air find their real explanation in the fact that the law of Dalton is only approximately true in the case of mixtures of air and aqueous vapor at the ordinary pressure and temperature of the atmosphere, and do not depend, as has been alleged, on any disturbing influence produced by a hygroscopic action of the sides of the containing vessel. The law of Dalton, in short, like the laws of Boyle and Gay-Lussac, only holds good in the case of gaseous bodies which are at feeble pressures and at temperatures greatly above their critical points. Under other conditions these laws are interfered with; and in certain conditions (such as some of those described in this note) the interfering causes become so powerful as practically to efface them.

The Use of Natural Gas Extending.—The highly satisfactory results obtained by the use of natural gas in puddling and heating furnaces at Erie, Leechburg, and other places in Pennsylvania, has induced a serious effort to bring this excellent fuel from the great gas well in Butler county, Pennsylvania, to the ironworks of Graff, Bennett & Co., and Spang, Chalfant & Co., in Pittsburgh.

It is proposed to use a pipe 6 inches in diameter, and 17 miles long; this will be carried in a trench 3 feet deep, and the work is under contract to be finished within a month.

DANA'S CORALS AND CORAL ISLANDS.*

The additions which Professor Dana has made to his work on Corals and Coral Islands,† in preparing his second edition for the English public, have made it the fullest and most advanced repertory of knowledge upon that interesting and still novel branch of natural history. Without sacrificing scientific precision he has succeeded in presenting the subject in a form intelligible to the ordinary reader, and in surrounding what might otherwise have been dry details and cumbrous technicalities with the charm with which a true lover as well as master of nature never fails to invest his theme. To the labors of those who have led the way, and to whom he fully acknowledges his obligations, he does justice in his prefatory observations. It will be seen at the same time that he is no mere compiler from the results of other men's research and observations, having himself had chief charge of the scientific corps under command of Admiral Wilkes in the United States Exploration of the Pacific from 1838 to 1842. The preliminary announcement of the great theory of coral-reef formation by Darwin came in happily to give a guiding light to the investigations awaiting the expedition. And of the fuller explanations since brought out by that great naturalist Professor Dana has not failed to avail himself, whilst adding new facts and scientific solutions in abundance from his own independent researches and from valuable works like those of Johnston, Hincks, and Gosse. The illustrations with which the book abounds are of great service, bringing vividly before the eye the variety and beauty of the manifold forms of coralline growth and structure, and imparting additional clearness to the writer's descriptions.

The popular mind has been all along under much misapprehension as to the nature and growth of corals, speculation or even superstition having largely held the place of facts. A special mystery has been supposed to attach to the domain and the functions of these minute "animalcules," as it was thought most fitting to designate the submarine workers. The use of such terms as polypary and polypidon sufficiently expresses the popular notion that each coral was the house or hive of a swarm of polyps, like the honeycomb of the bee, or the

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*From the *Saturday Review*, London, August 14th, 1875.

†*Corals and Coral Islands.* By James D. Dana, LL.D., Professor of Geology and Mineralogy in Yale College, etc. London: Sampson Low & Co. 1875.

hillock of a colony of ants. Even now that the extended taste for natural history, and the general familiarty with the contents of aquariums, have made the more intelligent part of the public familiar with the commoner forms of polyp growth, there is no little difficulty in realizing the process whereby, through the agency of soft molluscous tissues, which alone meet the eye, a substance of such hardness, and masses of such stupendous depth and volume, have been built up. There is however, after all, no greater mystery in a polyp forming structures of stone or carbonate of lime in continuous masses than in a quadruped forming its bones, or a mollusc or crustacean its shell. It is a simple case of secretion, and no more—a process among the first and most common of those which belong to living tissues: differing, indeed, in different organs in accordance with their end or function, yet essentially identical, whether in the animalcule or in man. It is most characteristic of the lowest kinds of life. Not that all polyps have equal powers of secretion, or that they can carry on their functions under all external conditions alike. But among them are found the greatest stone-makers. In their simplicity of structure they may be almost all stone, and still carry on the processes of nutrition and growth. Theirs has been the task throughout geological time of producing the material of limestones and marbles, consolidating under water the solid rocks which were one day to be upheaved and to form islands and continents for the abode and the study of man.

Mr. Dana's exhaustive treatment of his subject leads him to prepare the reader for the comprehension of the origin and distribution of reefs and islands by distinguishing between those organisms which have the secreting power and those which have not. Coral is never the handiwork of the many-armed polyps, these organs being no more concerned in the lime-secretion than our limbs or muscles are in bone-making; nor does coral partake of the nature of the cell into which the animal may withdraw itself like certain molluscs. Poets have drawn fancy pictures of the toil and skill put forth in the elaboration of coral masses, or of the shapeless worms which they conceive to writhe and shrink in the process; but nothing can well be further from the actual formation of the *carallum*, as the coral skeleton is called, which is secreted among the tissues of the sides and lower parts, not the stomach or the tentacles of the polyp. To the compound mass

produced by a process of budding analogous to that in vegetation, and consisting of several polyps with the corallum as their united secretion or base, the name of zoophyte has been generally attached, it being truly animal in nature, though plant-like in point of budding. As this term, however, conveys to many minds the idea of something between a plant and an animal, which is false, Professor Dana would substitute for it *zöothome*, from ζωου, "animal," θωμος, "a heep," a term no less applicable to compound groups in other classes—*e.g.*, Rhizopods, Bryozoans, and Ascidians.

Besides polyps, which are the most important of the coral-reef builders, there are three other classes of organisms which secrete corallum. These are the Hydroids, related to the little hydras of fresh waters, forming the very common and often large corals called millepores; the Bryozoans, or lowest tribe of molluscs, deriving their name from the delicate moss-like corals they secrete, no longer prominent as builders, but in Palæozoic ages so abundant that some beds of limestone are half composed of them; and certain Algæ or seaweeds, barely distinguishable from true corals, save that they have neither cells nor pores. Each group is subjected to careful and minute classification by the author, the plentiful and beautifully defined woodcuts greatly aiding the mind of the reader. Following in general the limits of tribe and species assigned by Professor Verrill, he gives reasons for diverging from them in some cases. He unites, for instance, both the non-coral making and the coral-making species into one grand division, that of the Actionids, on the ground of the close resemblance of the polyps; and he also separates from the latter the Cyathophylloid corals, which differ from them in having the number of tentacles and interior septa multiples of four, a characteristic of the Alcyonoids, instead of six. In external aspect and in internal character all are essentially identical, the general type being that of the sea-anemone. In all alike the processes of life and death are for ever going on together *pari passu*, the coral secretions giving to the polyp a base whereon to mount upwards, lengthening itself at the top by the formation of fresh cells. It thus leaves the dead corallum behind as the upward growth proceeds, so that a polyp but the fourth of an inch long, or even shorter, is often found at the top of a stony stem many inches in height. In *Goniopora columna*, for example, the living part combines a vast number of living polyp-cells, growing and bud-

ding with rich exuberance, while below the old polyps have undergone the process of death, their cells retaining no distinction of surface, and blending into a uniform mass, disclosing, however, imbedded shells. Madrepores may branch into trees almost without limit, all below a slight distance from the summit being dead, this distance varying in different species; the dead coral below serving as an ever-rising basement of rock, often harder than ordinary limestone or marble, for the still expanding and rising zoothome. The large domes of Astræas, attaining, as they are said to do, a diameter of ten or fifteen feet, and alive over the whole surface, owing to a uniform and symmetrical mode of budding, are throughout the whole interior nothing but lifeless coral. Could the living mass which meets the eye be separated it would form a hemispherical shell of polyps, in most species not more than half an inch thick. There is thus no limit to the possible growth of corals. The rising column or dome may increase upwards indefinitely until it reaches the surface of the sea, when death ensues from exposure to the air, and not from any failure in the powers of growth. If the land supporting the coral domes or trees goes on gradually sinking, the upward increment may proceed till a thickness results of many thousand feet. Subsequent upheaval above the surface of the sea will result in mountain ranges of limestone or coral rag, which are known to have a thickness not much short of a mile.

The composition of coral forms an important part of Professor Dana's inquiry. Ordinary corals have a hardness a little above that of common limestone or marble, giving out a ringing sound when struck with a hammer. This may be owing, he considers, to the carbonate of lime being in the state of aragonite. It is a common mistake to suppose that coral, when first taken from its watery bed, is soft, and hardens through exposure. The live coral may feel somewhat slimy in the fingers, but if the animal matter be washed away it is found quite hard. Chemically the chief constitutent of all is carbonate of lime, in the proportion of 95 to 98 parts in 100, with $1\frac{1}{2}$ to 4 parts of organic matter, and some earthly ingredients, such as phosphate of lime, with a trace of silica, amounting usually to less than 1 per cent. Forchhammer found 2·1 per cent. of magnesia in *Corallium rubrum*, and 6·36 in *Isis hippuris*. The sources of these constituents are the sea water and the ordinary food of the polyps, the process of absorption, assimilation, and secretion going on in them as in all animal or-

ganisms. A zoophyte, be it kept in mind, is as much an animal as a cat or a dog is.

Since Mr. Darwin's luminous exposition of the origin and growth of coral reefs and atolls, nothing remained but to multiply illustrations of the working of this great primary law, besides collecting such facts as might futher define the limit or local conditions of its action. Professor Dana's wide range of observation gives to his book its special value in regard to the causes which influence the growth and distribution of corals. These causes are most directly traceable in relation to latitude, to depth, and to local influences. Whether or not the coral-making polyps are organically distinguishable from others, it is abundantly clear that a certain minimum of temperature is essential to the formation of coral. Coral-building is confined to waters which through even the coldest months never sink below 68° F. A pair of isothermal lines crossing the ocean where this is the winter temperature of the sea, one north and another south of the equator, each bending in its course toward or from the equator wherever the marine currents change its position, will include all the growing reefs of the world, and the included area of waters may properly be called the coral-reef seas. This isocryme, or cold water line, of 68° F., is far from coincident with latitude. The author's chart shows at a glance the extent to which observation has thus far found it to range. It extends through mid-ocean in both the Atlantic and Pacific basins near the parallel of 28°, but varies greatly from this in the vicinity of continents, and accordingly affects to a corresponding degree the geographical distribution of reefs. This is of course but a temporary extreme, the summer heats greatly raising the temperature. The mean for the year is about 73½° in the North Pacific and 70° in the South, the summer mean being as high at least as 78° and 74°. Over all this area coral-reefs grow luxuriantly, but in the greatest variety and richness where the waters are hottest. A torrid and a sub-torrid region, as drawn out by Professor Dana, will be found to correspond closely with a marked difference in coral-growth. Not only, however, are the reef-building species separable generically from those of colder seas, but there are specific differences by no means to be accounted for between corals of seas identical in temperature. Thus not a single West Indian species occurs on the Panama coast, although on the Aspinwall side there are found nearly all the reef-building species of

Florida, nor is any West Indian species known to be identical with any from the Pacific or Indian Ocean. While, therefore, temperature has much to do with the distribution of reefs in latitude, there are certain local peculiarities which are not thus to be accounted for.

Contrary to the notions of early navigators, who judged from finding coral-reefs at immense ocean depths, the growth of coral is now known to be limited to a very narrow depth of water. What their soundings brought up were specimens of deposits sunk long ago, and far below their living bed. The range within which the polyps live is nowhere found much to exceed twenty fathoms, whilst they die immediately on exposure at the surface. This may be taken as the limit of coral life. A further condition is the necessity of pure ocean water, mud or sediment being as fatal to the coral polyp as to the oyster. At the mouths of great rivers consequently they will be looked for in vain. A more recondite cause must be sought for the absence of corals in certain areas where there are no mud-banks, volcanic action being almost certainly in some way concerned. That the effect of volcanoes in raising the temperature of the waters, or chemically affecting them, had been underrated by Mr. Darwin, was an opinion put forth by Professor Dana in the earlier edition of his book. In reply to this the question has been asked by Mr. Darwin, by what means could the heat or poisonous exhalations from a volcano affect the whole circumference of a large island? We are surprised to find this point, on which we dwelt in noticing Mr. Darwin's recent new edition, left here without further proof or illustration. The most important accessions of new matter relate to the extent and depth of ocean subsidence, as shown by the able observations of General Nelson upon the Bahamas, and those of Mr. Matthew Jones upon the Bermuda group, with correlative proofs of the like geological changes over the wide area of the Pacific. A great secular movement of the earth's crust may be inferred from these considerations, or rather the one local movement may be taken to have balanced the other. A vast Southern area, equal to one-quarter of the earth's circumference, sinking to the extent of perhaps ten thousand feet, must have caused a revolution in which the whole sphere of the earth must have been concerned. It accompanied, we may well believe, the immense upward movement of the North American continent preparatory to or during the great Ice epoch. This range of elevation and depression

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is not indeed great compared with the upheaval which the Rocky Mountains, the Andes, Alps, and Himalayas have each undergone since the close of the Cretaceous era or the early Tertiary. Even our own country shows signs of disturbance not far short of this, and boundless time must be allowed for the accumulation of the Pacific reefs and atolls, considering the depths to which the adjacent soundings bear witness. All seems to confirm the belief that the main continental outlines of land and water have remained the same throughout. Oceans have always been oceans. Yet from the configuration of the North American continent, combined with that of the adjacent reefs, it may be judged that the peninsula of Florida, Cuba, and the Bahamas were once part of a vast prolongation of the southeastern angle of the continent, a submerged ridge being traceable between Florida and Cuba. The lonely Bermuda atoll confirms by its position the same deduction. The submerged coral banks on either side show that it is not wholly alone, but forms a summit in a long range of heights. So in the Indian Ocean the oceanic area was correspondingly affected by the coral island subsidence. As the islands or high lands sank beneath the sea, the corals built up their encircling walls. If the rate of subsidence kept up at all a corresponding pace with the coral secretion, the resulting atoll ring rose up as a crown far above the sinking intermediate cone, standing up from the ocean floor a monument to mark the site of the buried islet. A rate of sinking exceeding five feet in a thousand years would, according to the estimate arrived at by the author, as well as by most competent calculators, have buried islands and reefs together in the ocean.

Coming nearer home, the most lively interest for us centres in the question, under what conditions of temperature and depth were built up the thick masses of coral which enter into the limestone system of the British Islands, not to speak of the extensive Continental range of dolomite or magnesian carbonate of lime into which coral structure has been shown by analysts largely to enter. Did the isocryme of 68° extend as far as our northern seas, some vast divergence or expansion of the equatorial current, misnamed the Gulf Stream, imparting the necessary heat to our sub-temperate seas? or did a hardier class of corals keep up life and work in these northern latitudes? Beyond doubt, a coral reef of the Astræ tribe, and wide madrepore deposits during part of the Oolitic era (middle Jurassic), bear witness

to the active presence thus far north of zoophytes, which are now only found at work in tropical or sub-tropical waters. Upon this suggestive and pregnant fact, Professor Dana touches sufficiently to prove that he estimates aright its weight, and the vast width of its bearing. We hope to see it pursued more fully, and studied with the same keenness of apprehension, and the same patient elaboration of truth which characterizes the work before us.

RULES FOR CALCULATING THE WEIGHT OF ONE FOOT IN LENGTH OF ROUND, SQUARE, OCTAGON, HEXAGON, AND FLAT STEEL.

By W. F. Durfee, Engineer.

The following rules for computing the weight of a lineal foot of those sections of steel in common use, have, in the absence of tables, been found by the writer, very convenient and sufficiently accurate for most practical purposes.

Rule for Round Steel.—Square the numerator of the fractional expression of the diameter of the bar whose weight is required, and divide this square by the number in the following table placed opposite the denominator of the fractional expression taken, and the result is the weight in pounds of one foot in length. If the diameter is expressed in

64ths	of	inches,	divide	the	square	of the numerator by 1536·
32ds	"	"	"	"	"	384·
16ths	"	"	"	"	"	96·
8ths	"	"	"	"	"	24·
4ths	"	"	"	"	"	6·
½	"	"	"	"	"	1·5

If the diameter is expressed in

Inches, divide the square by . . . 0·375

Example.—Required the weight of one foot in length of ⅞ths round steel: $7 \times 7 = 49 \div 24 = 2{\cdot}0416$ lbs. per foot.

Rule for Square Steel.—Square the numerator of the fractional expression of the side of the bar whose weight is required, and divide this square by the number in the following table placed opposite the denominator of the fractional expression taken, and the result is the weight in pounds of a foot in length. If the side of square is expressed in